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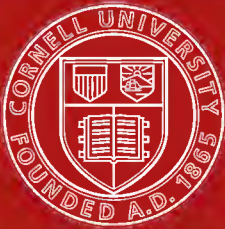
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MEMOIRS OF THE GEOLOGICAL SURVEY
ENGLAND AND WALES
EXPLANATION OF SHEET 353

THE GEOLOGY OF
THE COUNTRY AROUND
MEVAGISSEY

BY

CLEMENT REID, F.R.S.

WITH PETROLOGICAL CONTRIBUTIONS BY
J. J. H. TEALL, D.Sc., F.R.S.

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PREFACE.

The country around Mevagissey which is described in this memoir is illustrated in Sheet 353 of the New Series one-inch map. The original survey of this area was made by De la Beche on the Old Series one-inch map, Sheet 31, and the results were published in 1839. The presence of limestone, quartzite and igneous rocks in the area in question is recorded on the early issues of this sheet, and they are represented as occurring in what was then known as the Grauwacke Series.

In the same year, that is in 1839, the second part of the classic paper by Sedgwick and Murchison "On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified Deposits," in which the "Devonian System" was definitely established, was read before the Geological Society of London; and a few years later C. W. Peach announced his discovery of Silurian fossils within the area to which this memoir refers. These advances in knowledge made it clear that the old Grauwacke Series of De la Beche would have to be subdivided, and on later issues of the Old Series map a crude attempt to indicate by colour the distribution of Devonian and Lower Silurian rocks, evidently based on Peach's discoveries, was made; but no definite line was engraved.

The recognition of the Lower Silurian (Ordovician) age of some of Peach's fossils, was made in 1846 by Murchison, who observed: "In pursuing his researches, Mr. Peach published in 1844 a synopsis of the Cornish fossils from various localities, in which, besides the ichthyolites of Polperro, he identified several mollusca from Gorran Haven, Caerhayes, and Carn Gorran Bay, with typical Silurian species. These were the fossils I was so anxious to see at Penzance; and Mr. Peach having obligingly forwarded them to me in London, I no sooner unpacked the box, than I found that true Silurian and even Lower Silurian rocks existed in Cornwall." Although, as Murchison adds, the specific names attached by Peach to his fossils were not correct, yet he "had come to a correct general conclusion." Moreover "the energy of Mr. Peach having thus afforded us the key by which new lights are thrown upon the succession of Cornish strata, I cannot but hope that when the Government geological surveyors revisit Cornwall, they will define the exact demarcations between these Silurian masses and their overlying Devonian neighbours." This task has now been attempted, and the results, so far as the area around Mevagissey is concerned, are recorded in Sheet 353 of the New Series one-inch map, and in the corresponding six-inch maps which have been deposited for reference in the Library of this Institution.

On comparing Sheet 353 with the corresponding area in the later issues of Sheet 31 (Old Series), it will be observed that the most important additions are the definite separation of the Devonian from the older rocks, the subdivision of the former into Grampound Grits and Meadfoot beds, and of the latter into

the Dodman, Portscatho and Veryan series. In the course of the new survey there has been a curtailment of the area that was represented as Lower Silurian on the later issues of the old map near Gorran Haven. On the other hand, between Veryan and Tregony a large tract, now grouped as Portscatho Beds, is included in the pre-Devonian area on evidence which is given more fully in the Falmouth memoir.

The area included within Sheet 353 has been surveyed by Mr. Clement Reid, who is also responsible for this memoir, except as regard some of the petrographical and palæontological details.

It is our pleasure to have to acknowledge assistance from many workers. Mr. Upfield Green's recognition of Silurian (Upper Silurian) fossils in the limestone lenticles of Porthluney Cove is of great interest; and both to him and to Mr. C. D. Sherborn, his friend and co-worker, we are indebted for information ever readily placed at our disposal. Mr. Howard Fox, whose detailed work on the distribution of radiolarian cherts has proved of great value in mapping, has also aided us. Our thanks are likewise due to Mrs. Reid for her valuable aid in the search for fossils, and to Mr. Lake, Dr. C. A. Matley, Mr. G. C. Crick and Dr. F. A. Bather for the trouble they have taken in the examination and identification of all available palæontological material.

To Mr. J. C. Williams of Caerhays we are indebted for specimens of the soda-felsite of Trevennen; and to the Corporation of Trinity House for specimens of gneiss from the Eddystone rocks. And finally we have to thank Dr. B. N. Peach for presenting to our Library the original tithe map of Gorran Parish, on which his father recorded the localities from which he had obtained fossils. This interesting historical document shows that with one or two exceptions all the localities from which fossils of zonal value have been obtained were known to him.

In conclusion attention may be called to the description of the peculiar features of the important line, or rather zone of disturbance which may be followed from Gorran Haven to the shores of Gerrans Bay. The fossils that have been obtained do not come from one, but from several horizons, and they are not met with in beds that can be traced throughout, or found elsewhere in the district, but in lenticular masses which occur in this zone and owe their form and position to powerful earth-movements. It seems probable that this disturbance is connected with that of the Start on the east and of the Lizard on the west; and it is worthy of note that a line joining these disturbances is approximately parallel to one joining the centres of the principal masses of granite in Cornwall and Devon.

J. J. H. TEALL,
Director.

*Geological Survey Office,
28, Jermyn Street, London.
12th July, 1907,*

NOTE.

The following is a list of the six-inch geological maps included in the area ; MS. coloured copies of them are deposited for public reference in the Library of the Museum of Practical Geology :—

Cornwall,	58	N.E.	Trewithen.
"	"	S.E.	Tregoney, River Fal.
"	59	N.W.	Grampound, Creed.
"	"	N.E.	St. Ewe, Pentewan.
"	"	S.W.	Cuby, Tubbs Mill.
"	"	S.E.	Mevagissey, Trevarrick.
"	60	N.W.	Black Head.
"	"	S.W.	Chapel Point.
"	65	N.E.	Veryan Green.
"	"	S.E.	Veryan, Nare Head.
"	66	N.W.	Veryan, Caerhays, Porthluney.
"	"	N.E.	Gorran Haven, The Dodman.
"	"	S.W.	Portloe, Blouth Point, Gull Rock.
"	"	S.E.	(with 66 N.E.).
"	66a	-	The Gwineas.

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}
At end.

GEOLOGY

OF THE COUNTRY AROUND

MEVAGISSEY.

CHAPTER I.

INTRODUCTION.

The district to be described in the following pages includes only an area of about 36 square miles in South Cornwall, from the Dodman Point to within a few miles of St. Austell, and nearly to Grampound. Within it lie the small towns of Mevagissey and Tregoney, and the villages of Gorrana, Veryan, Portloe, St. Ewe and Creed. The country may be described briefly as a tableland, seldom exceeding 300 feet in height, and much cut into by deep valleys, which reach nearly to the sea-level. The Fal crosses diagonally its north-west corner, the St. Austell River traverses its north-east for about a mile. Other small streams rise within or just outside the area, each holding an independent course to the sea, their direction of drainage having been decided by the seaward slope of the plateau, which is so general in Cornwall.

The coast is exceedingly rugged and rocky, but as a rule the cliffs, owing to the seaward slope of the plateau, do not exceed 200 feet. There are two exceptions, however, for the Dodman Point rises seaward and ends in a bold headland and cliff 375 feet in height, without outlying rocks, though it will be observed that the submarine contour suggests that the headland once extended a mile and a half further south. Nare Head (which must not be confounded with the Nare Point, near St. Anthony) is the other exception. It, like the Dodman, is separated from the plateau by low ground, and then rises seaward to a height of 331 feet, which corresponds with the height of the plateau several miles inland. Nare Head also is continued seaward for about a mile, as is shown by the submarine contours; but unlike the Dodman, on this submerged ledge the hard greenstone still rises to the sea-level in several dangerous reefs, and in one rocky islet which reaches 100 feet. Black Head, the southern point of which just enters the northern margin of this area, practically belongs to the St. Austell district; it is a bold headland of greenstone.

Though the area to be dealt with is so small, it includes some of the most puzzling geology in Cornwall, and it is not surprising

that in De la Beche's original map, published by the Geological Survey as far back as 1839, the sedimentary rocks were coloured simply as "Grauwacke series," with bands of quartzite and limestone, and with volcanic masses. After C. W. Peach's discovery of fossils, identified by Murchison as Lower Silurian,¹ a wash of Silurian colour was put on the map to include this fossiliferous area between Gorran and Veryan, the rest of the sheet being coloured as Devonian; but no real division was made, and a boundary appears later to have been engraved merely as a guide for the colourist.

The real working out of the structure of this area has thus been a very slow process, aided by many observers, and lastly by the re-mapping of the whole area by the Geological Survey. But it should at once be stated that there is no finality in this work—there is enough unexplained in this small area to employ a skilled geologist for several years longer, and there is also plenty of work for the fossil collector and petrologist. We seem to have cleared up certain points which have always puzzled geologists; but we appear to have raised more questions than we have settled—as is usually the result of a more accurate survey. The officers of the Survey have only a limited time, and are obliged soon to move on to other areas, leaving the new map and memoir as a guide for future workers, rather than as finished productions. It is hoped that the following pages may help future observers, by indicating where special research is required. In order to do this, details of the exact position and characters of peculiar sections are added more freely than at first sight would seem to be required. The coast is in most parts very much indented and difficult of access, and without clear guidance much time will be lost in trying to find the spots indicated.

As most of the best sections are only accessible at low water, or at any rate are most easily reached at low tide, attention should be paid to the state of the tide. At new and full moon low water occurs at about 11 o'clock, the lowest tides of the month coming about two days afterwards, at about half-past 12. This gives very convenient mid-day tides; but if the more difficult parts are to be visited, an early start should be made, so that the falling rather than the rising tide may be used, otherwise if a mistake is made it may be impossible to re-pass certain headlands that can only be rounded for an hour or two. The extremely rocky nature of the coast and the heavy swell make it impossible to use boats for landing, save on exceptionally calm days.

LITERATURE.

The literature relating to this area divides itself into two classes, the one referring to the old rocks, the other to the drift and stream-tin of Pentewan. We will here mention merely the leading publications relating to the older deposits, in order to show the gradual working out of this difficult country. The

¹ *Trans. R. Geol. Soc. Cornwall*, vol. vi., 1846, p. 319.

papers relating to the alluvium will be dealt with more conveniently in Chapter VI.

The earliest attempts to work out the geological structure of this area were made soon after the foundation of the Royal Geological Society of Cornwall, which gave a great impetus to the study of geology throughout the south-west of England. In the first volume of its publications S. J. Trist gives notes on the limestone of Veryan.¹ Incidentally he mentions that this limestone was discovered as far back as 1796, and was quarried for manure and masonry till about 1810, and also burnt for lime. He gives a map showing the strike of the limestone, which runs about north-north-east to Polcouth. Further particulars are given in a later paper in the same volume, by the Rev. J. Rogers.²

The next reference to the district did not appear till 1832, when Dr. Boase published his 'Contributions to a Knowledge of the Geology of Cornwall.'³ In this descriptions are given of specimens of rocks from different parts of the country; but few of these specimens came from the area with which we are now dealing.

The 'Report on the Geology of Cornwall, Devon, and West Somerset' by De la Beche, published in 1839,⁴ devotes 4 pp. to this area. It points out the continuity of the conglomerate of Pentuan with the grit of Grampound, and gives a number of details, some of which seem to have been obtained from C. W. Peach, who had already found fossils, though these had not yet been recognised as differing from Devonian species, and his work was still unpublished. De la Beche noted for the first time many details; but accepting the high angles of the strata as representing true dips he missed the real structure of the area. Unfortunately also until the last few years everyone has confused the crush-breccias with the true conglomerates, so that in De la Beche's section in 'descending order' between Dodman and Portholland there are four conglomerates, two of which are conspicuous bands of crush-breccia, whilst the other two represent the same band of conglomerate repeated by a fold. De la Beche was the first to note the occurrence of serpentine and diallage rock in Kiberick Cove, which he speaks of as a 'small outburst.'

In 1841⁵ came two papers by C. W. Peach, in which he described the rocks of the coast between Gorran and Veryan, noting the occurrence and range of the fossiliferous quartz-rock, and of the fossiliferous limestone conglomerates of Perhaver Beach and Porthluney. These were followed in 1842⁶ by another paper, in which Peach tabulated the fossils he had

¹ 'Notes on the Limestone Rocks in the parish of Veryan.' *Trans. R. Geol. Soc. Cornwall*, vol. i., 1818, p. 107.

² *Ibid.* p. 114.

³ *Ibid.* vol. iv., p. 166.

⁴ *Geological Survey*, 8vo. London [pp. 82—85].

⁵ 'An Account of the Fossil Organic Remains found on the South-east coast of Cornwall. . . . ' *Trans. R. Geol. Soc. Cornwall*, vol. vi., p. 12; and, 'On the Geology of part of the Parish of Gorran, in Cornwall,' *ibid.*, pp. 51—58.

⁶ 'On the Fossil Geology of Cornwall,' *ibid.* 180—184.

found and determined; but these determinations do not now stand.

A paper by Sir R. I. Murchison was published in 1846¹ and this seems to contain the first recognition of Lower Silurian rocks in Cornwall, founded on fossils collected by Peach and determined by J. de C. Sowerby. The strata were referred with doubt to the upper portion of the Caradoc Sandstone. About the period when Murchison succeeded De la Beche as Director-General of the Geological Survey the colouring of the Survey Map was altered, the slaty rocks or killas being differentiated into Devonian and Lower Silurian. No line, however, was drawn, but the somewhat indefinite colour-boundary corresponds approximately with the limit of the quartzite as given by Peach.

The map last referred to appears to be a copy of the Tithe Map of Gorran Parish, on the scale of about three inches to a mile. On this map Peach has laid down the position of the different beds noticed by him on the coast from Great Perhaver and Gorran Haven to Hemmick and Porthluney. The inland area has few notes, and there are no boundary lines, except a pencil line joining the main quartzite outcrops. This most interesting map has been given to the Survey by Dr. B. N. Peach, son of C. W. Peach, and it is now before me. When we remember that it is one of the earliest attempts accurately to lay down on a large-scale map the exact position where certain fossils and peculiar rocks were found, and that Peach never professed to work out their stratigraphical relations, it is an exceptionally valuable piece of work. The line on this map connecting the quartzite of Great Carn with that of Diamond Rock near Porthluney is obviously only intended as a line showing approximately the strike of a particularly conspicuous band. On either side of the line the rocks are coloured alike as 'argillaceous schist.' Peach's map only includes Gorran parish, and he does not appear to have made any map beyond the limits of Gorran. His map is not dated; but we learn from the President's address to the Royal Geological Survey of Cornwall for 1842, that it was completed in that year.

In 1851 Sedgwick and McCoy visited Gorran Haven, and McCoy determined certain Lower Silurian fossils collected by Peach and deposited in the Penzance and Truro Museums.²

Salter's 'Monograph of British Trilobites'³ carried the matter a step further, he identifying and figuring *Calymene Tristani*, a species belonging to the *Grès de May* of Brittany, the deposit with which the Gorran quartzite is now correlated. He also referred the quartzite to the 'Llandeilo (or Arenig) Rocks.'

In 1879,⁴ 1881,⁵ and 1884⁶ Mr. J. H. Collins published papers and a map, the latter differing greatly from either the old or the

¹ 'A brief review of the Classification of the Sedimentary Rocks of Cornwall,' *ibid.* p. 317.

² *Quart. Journ. Geol. Soc.*, vol. viii., p. 13.

³ *Paleontographical Society* for 1864.

⁴ *Trans. R. Geol. Soc. Cornwall*, vol. x., p. 1.

⁵ *Journ. R. Inst. Cornwall*, 1881, p. 18. ⁶ *Ibid.* 1884, p. 162.

new maps of the Geological Survey. He considers that four unconformable masses occur in the killas of Cornwall.

Mr. W. A. E. Ussher in 1891 published a very suggestive paper,¹ accompanied by a map on which he tentatively placed the Grampound Grit at the base of the Devonian System, overlying pre-Devonian rocks in West Cornwall. The attempt to separate the rocks was based on his interpretation of facts recorded by De la Beche, and although admittedly vague was an advance on the earlier maps of Mr. Collins, inasmuch as it contains a more accurate suggestion of the division between the strata of Mid and West Cornwall so recently demonstrated by Mr. Hill.

No further advance appears to have been made till 1896, when Mr. Howard Fox published a paper on the 'Radiolarian Cherts of Cornwall.'² This gave a clear description of the deposits and drew attention to the occurrence of the chert over a long belt of country, thus adding greatly to the certainty of the correlation. It was followed in 1898 by another paper on the 'Veryan and other Limestones associated with Radiolarian Cherts in South Cornwall.'³ In 1899 Mr. Fox added some 'Supplementary Notes on the Cornish Radiolarian Cherts and Devonian Fossils.'⁴

These papers by Mr. Howard Fox have been of the greatest assistance during the new survey, for not only has he discovered and laid down on the map nearly all the exposures of radiolarian chert, but he also found near Mevagissey some slates with cherty seams which Dr. Teall examined and found to be manganiferous siderite. Bands of this peculiar character have since turned out to characterise a narrow belt in the Lower Devonian extending from sea to sea, coming out on the north coast close to Perranporth.

The resurvey of West Cornwall was started in 1897 by Mr. J. B. Hill who in the *Summary of Progress* for that year (pp. 78, 79) pointed out that the killas of Gerrans Bay was enormously plicated and faulted, and that thin strata have been so repeated by isoclinal folding as to give a fictitious value to its apparent thickness. Previous writers had been misled as to the great thickness of the Cornish strata through not recognising this fundamental structure of the Cornish killas. In the following year Mr. Hill showed that the strata of Gerrans Bay, including the Lower Silurian fossiliferous quartzite of Carne that was coloured Silurian on the old map, formed a natural sequence with the slates of the adjacent area to the westward coloured on the old map as Devonian. He further divided the killas into four divisions as follows:—

The Veryan series, comprising that part of the sequence coloured on the old map as Silurian.

The Portscatho series,
The Variegated series, } coloured on the old map as Devonian.
The Mylor series,

¹ 'The Devonian Rocks as described by De la Beche interpreted in accordance with Recent Researches.' *Trans. R. Geol. Soc. Cornwall.*, vol. xi., pp. 173-227.

² *Ibid.* vol. xii., p. 39.

³ *Ibid.* p. 179.

⁴ *Ibid.* p. 278.

The Variegated series was subsequently called by Mr. Hill the Falmouth series. He also, in a paper to the Royal Geological Society of Cornwall,¹ indicated certain analogies between the geological phenomena of the Southern Uplands of Scotland and South-west Cornwall (*Summary* for 1898, pp. 97-103).

In 1899 Mr. Hill showed (*Summary* pp. 88-95) that, besides the structures already alluded to, the killas contained widespread crush-breccias of a regional type. He pointed out that the close plication, faulting, and thrusting of the killas was such that the order of succession could only be provisionally determined. Mr. Hill further confirmed the work of De la Beche and Mr. Collins by correlating the conglomerates of the Gerrans Bay area with those south of the Helford River, both of which, as already shown by former observers, contain boulders of the quartzite. From the evidence of these quartzite boulders Mr. Hill concluded that this conglomerate represented an unconformity indicating a considerable break. In the same year Mr. Hill communicated his results to the Royal Geological Society of Cornwall, in a paper wherein he showed how his investigations on the killas structures gave a new reading to the stratigraphy of West Cornwall, and that the apparent thicknesses of the strata were exaggerated by repetition. He instanced the Carne quartzite as an example of thickening by packing so as to make a narrow bed occupy a wide outcrop. He further showed that the four divisions of the sequence already alluded to spread practically over the whole of West Cornwall.

In 1901 Mr. Hill recorded at Gorran Haven for the first time the existence of pillow lavas similar to those of Mullion Island on a similar geological horizon, and referred to their great mechanical deformation with the production of crush-breccias. He further indicated the remarkable resemblance of the pillow lavas of Mullion Island and Gorran Haven with those of Ballantrae which he had examined in the same year, and suggested that the Cornish horizons were also Arenig. He pointed out also that fragments of the pillow lava were incorporated in the Nare Point conglomerate.

Later Mr. Hill indicated that the Grampound and Probus conglomerate might represent an unconformity between Silurian and Devonian rocks. It was also recognised as the equivalent of the Nare Point Conglomerate, a fact confirmed by Dr. Flett from microscopic examination.²

In 1906 Mr. Hill definitely proved his contention of the pre-Devonian age of his four divisions by demonstrating the unconformity at the base of the Devonian, and he concluded from the evidence of the conglomerate that the Mylor group probably represents the base.

A great advance was made by Mr. Upfield Green, who re-discovered fossils in the limestone 'conglomerate' of Porthluney, in which Peach had previously found them.³ These fossils were examined by Messrs. Sherborn and Crick, who carried the matter

¹ 1899, see Appendix.

² See *Geol. Mag.*, 1906, p. 212.

³ *Geol. Mag.*, 1904, p. 289.

further, for they identified them as Upper Silurian, not Lower Silurian.

When the old records are studied and the constant discrepancies in the determinations are noticed, it must be remembered that the lists are made up from collections of mixed Lower and Upper Silurian fossils, made at a time when no one suspected that all did not come from beds of the same age. Each observer was trying to make badly preserved specimens fit into a homogeneous fauna, and it is not surprising that nearly all the determinations were wrong. The long lists given in Peach's later papers do not correspond with the species now to be found in his collections. Later in the year 1904 Mr. Prior described the pillow-lavas which he had seen with Mr. Green.¹

The detailed mapping of the Gorran area was commenced in 1904, and in the *Summary of Progress* for 1904 and 1905 a short account was given of the progress of the work; but as the results appear more fully in the following pages they need not be here referred to.

Messrs. Upfield Green and Sherborn returned to the question of the Silurian fossils in 1906, giving a list of those found by them at Porthluney.²

The formations represented in Map 353 are as follows:—

RECENT	{ Blown Sand. Alluvium and Submerged Forest.
PLEISTOCENE	{ Valley Gravel and Head. Raised Beach.
LOWER DEVONIAN	{ Gram-pound Grit and basal conglomerate. Meadfoot Beds (fossiliferous slate).
SILURIAN.	{ Lenticles of limestone and calcareous slate (with Ludlow and Wenlock fossils).
ORDOVICIAN	{ Gorran Quartzite. Veryan Series (slate, limestone, and radiolarian chert). Portscatho Series (slate and grit). Dodman Series (silty slates and phyllites).
IGNEOUS	{ Quartz-porphry (Elvan). Felsitic Ash (?). Basalt and Dolerite. Gabbro. Serpentine.
METAMORPHIC GNEISS	(of Eddystone).

¹ *Geol. Mag.*, 1904, p. 447.

² *Ibid.*, 1906, p. 33.

CHAPTER II.

LOWER PALÆOZOIC ROCKS OF THE COAST.

In the study of the coast the most convenient method to follow will be to trace the section across the strike from the Dodman northward through Gorran Haven, and then return to the Dodman and trace the same deposits westward to Veryan. Extensive and irregular overthrusting and folding make it impossible to follow any particular band in the Ordovician rocks far along the line of strike, and though the general correspondence of the two coasts is clear, details do not altogether agree. On the west, also, certain beds are represented, which, owing to the unconformity of the Devonian strata, are not seen around Gorran Haven.

As the coast is in parts difficult of access and geological changes are very abrupt, it has been thought best to describe it in such a way that, with the aid of the one-inch geological map and these notes, it will be possible to find without difficulty each section described. For this purpose details have been added as to paths, and small topographical landmarks have been referred to, in order that the exact position of each section may be found without reference to the six-inch maps—indeed many of the features and paths are so small that, though exceedingly useful for our purpose, they cannot be found on the six-inch map. No map would show some of the most curious deposits, which are only visible in the vertical face of the cliff.

This coast is in parts a somewhat dangerous one, and, as already observed, particular attention should be paid to the tides. If possible the days just after new or full moon should be selected for the examination. By choosing the days of these low tides much of the coast not readily accessible at other times can be examined with ease, and reached without much climbing or scrambling. In a few places the extreme low-water is also needed for the exposure of good sections, though this is seldom the case, for the rocks near low-water are usually too much obscured by weeds and barnacles for satisfactory examination. Certain parts of the coast should only be examined with a falling tide, so that if any mistake is made as to the path, it is possible to retreat by the original track; some of the coves have long horns running nearly to low-water and only passable at a single point.

The Dodman forms a bold headland rising to 375 feet near the point and bounded everywhere by steep cliffs. It is composed of a singularly uniform mass of pale-grey, fine-grained, soft slate or glossy phyllite, commonly with scattered cubes of pyrite, and locally much veined with quartz. It is well cleaved, and the

cleavage seems usually to coincide with the bedding, though the absence of beds of different lithological character makes any original bedding very difficult to distinguish. Some of the gnarled rocks at the foot of the cliff at the south end of Vault Beach show, however, undoubted signs of a crumpled folding cut across by regular cleavage. The usual dip of the cleavage planes is south-easterly, at 50° or thereabouts; this causes much slipping where the cliffs face the south-east; but where they face westward they are very steep and often quite unclimbable, as is seen in the Dodman and in Nare Head.

Besides this regular dip and strike, there are belts of strain-slip cleavage, with close, nearly vertical planes which throw the older cleavage into small wrinkles (see Plates 4 and 5). The rock, unlike the rest of the strata of this district, tends to split into soft flag-stones, which will stand the weather and are used locally for paving. The surface of these worn flags exhibits curious narrow bands of varying lustre, which show the ripple caused by the strain-slip cleavage. This ripple tends of course to interfere with the perfect cleavage of the flags, and in many cases the strain has gone so far as to cause the cleavage planes to divide and allow of the deposition of thin lenticles of quartz.

The common occurrence of isolated cubes of pyrite up to a quarter of an inch or more is very characteristic of the Dodman Rock, for all the other strata in the neighbourhood contain either disseminated pyrite or small crystalline aggregates. These cubes are commonly surrounded by an outer zone of whitish or pale-green quartz, which sometimes spreads in lenticular form along the cleavage planes.

It is scarcely necessary to begin at the extreme point of the Dodman, for most of it is only accessible from a boat, and rocks of identical character are excellently exposed at the south-west end of Vault Beach, which is easy to get at during low-water. The cliff and foreshore of Vault Beach call for little further comment, as we are following the strike of the same beds all the way. Attention should be paid, however, to the weathered stones in the 'Head' which clings to the cliff-face and rests on the raised-beach platform, for weathering brings out very clearly the distinctive characters of this rock. The quartz-veining is also curious. Little of it seems to be older than the cleavage, for sheared lenticles and fragments of vein-quartz, lying parallel to the cleavage and often striated, so common in the Veryan Slates, are absent. We find instead parallel wavy lenticles of quartz, where the strain-slip has caused the cleavage-planes to gape, and these are cut through by vertical sheets and veins of quartz of later date.

At the north-east end of Vault Beach, Cadythew Rock, and the surrounding platform a few feet above sea-level, represent the old raised-beach terrace, small patches of the shingle being found here and there beneath the Head which forms the steep cliff above. The weathered and water-worn surface of this raised-beach platform, and the Head above, show well the character of the rocks. The dip here is about 60° .

Pen-a-maen or Maenease Point is formed by a band slightly harder than usual, for it is continued by a crest or ridge running up the slope. Then follow softer strata, which near Scurvella Point yield rare calcareous streaks, and also lenticles of browner rock, probably once also calcareous. Another somewhat harder band forms the ledge on which the harbour wall of Gorran Haven has been built.

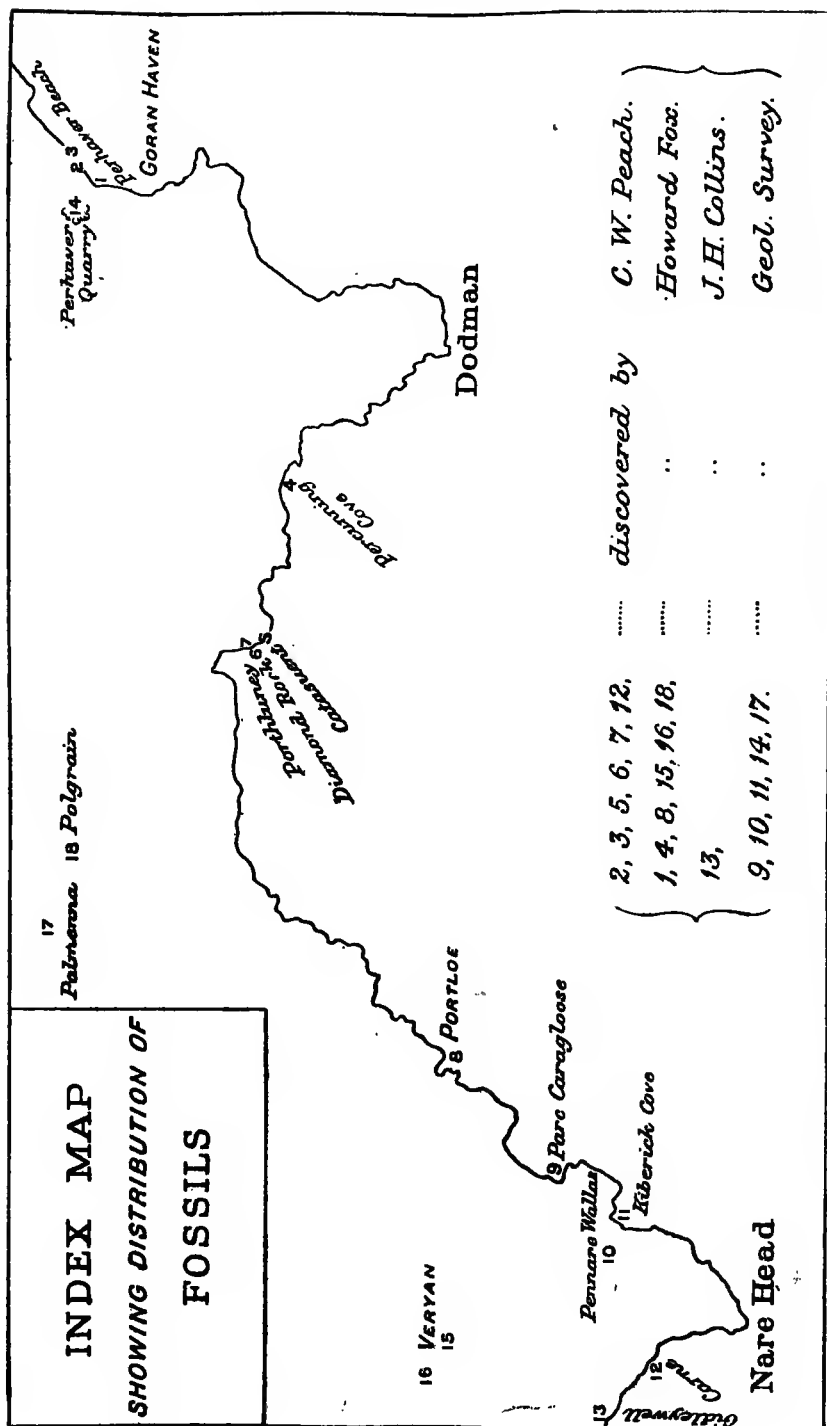
The sandy beach of Gorran Haven breaks the continuity of the section and no rock is visible near the stream. On passing the first house, pale-grey, perhaps ashy, wrinkled slates banded with red appear at the foot of the cliff. They strike about east-north-east, and undulate considerably, the dip varying from 50° to 70°. These slates continue as far as Little Perhaver Point, apparently becoming blacker and duller in that direction. They somewhat resemble the slates of the Dodman, but are coarser-grained; they may form a transition to the volcanic series, but it is more probable that they are cut off from the Dodman phyllites by a fault of considerable magnitude.

Little Perhaver Point is formed by a much-sheared pale felspathic tuff, greatly altered, and perhaps showing in the middle a narrow dyke of fine-grained rock. Behind the point, where the path runs down to Gorran Haven Beach, occurs a ferruginous, much weathered, silicified calcareous rock, probably from 2 to 4 feet thick, interbedded in hard quartz-veined slate. This band of 'limestone,' as it has been called, runs under the houses towards the Point, but is cut off, just before it reaches the Point, by a small fault. A good deal of tufa is deposited from the springs.

On the north side of the Point there is a good display of striped rocks coloured black, grey, and red, in thin laminæ, contorted and afterwards sheared. These alternate with the tuff. Then follow duller slate and tuff, with two bands of finely-laminated calcareous slaty tuff, the thicker of which reaches 10 feet and is cream-coloured inside. Here again there is much tufa deposited on the surface.

Little Perhaver Beach is occupied by softer black and grey slates, which tend to slip and form a bay. At the foot of the landslip occur many blocks of decalcified ferruginous rock, apparently fallen from the north side where the cliff rises. The upper part of the cliff in this bay shows 8 or 10 feet of Head. The stream and springs are very calcareous. The foreshore close to the cliff which bounds Little Perhaver Beach on the north shows ledges of black and banded slates, with thin seams of very fine grit or chert. Some of these were sliced, but no radiolaria could be found in them. The junction of these rocks with the lava next to be described is much sheared and consists usually of crush-breccia. It is perhaps a fault-line; but crush-rock nearly always occurs on this coast at the junction of two rocks of different hardness. This junction is excellently seen; for the cliff forms a dip-slope of lava, to which cling patches of the slate, which forms also a continuous ledge at its foot. At one point the junction is shifted a few feet by a later fault. Great Perhaver

FIG. 1.



Point is only passable at low-water spring-tides, and both it and Perhaver Beach are best approached by a rough track which descends the cliff close to the north wall of the ruined house of the abandoned ochre-mine. Another track will be found at the south-western corner of the landslip.

The volcanic rock which forms Great Perhaver Point is a greenish basaltic lava, with sheared lenticles of slate, dipping at about 70° or 80° to the south-south-east. Near the surface and on the southern face of the point it is buff and soft, in fact it answers to the local name of 'dun-stone.' At the sea-level and inside the mass the stone becomes tough and green, with a great tendency to the development of vesicles in its northern or originally upper surface. Fallen blocks show coarsely vesicular rock, from which the calcite has been removed, so that the mass again looks like a pumice. Here and there the surface of a fallen mass has a peculiar 'ropy' appearance, as though it were the original cooling surface; but the junction with the slates shown at the sea-level exhibits nothing of the sort, being sheared into thin laminæ which seem to pass into slate, except that there is an abrupt change of colour. The ochre-mine at the top of the cliff may have shown the top surface of this overturned sheet in a less disturbed state; but the workings are now overgrown.

On looking at the north face of Great Perhaver Point from the iron platform once used for shipping the ochre, one sees a flat joint-face cutting across the volcanic rock (see Plate 1). The face shows that the mass is entirely made up of lenticles of rock, which at first suggest that we have here a true 'pillow-structure,' caused by the rolling over of the pasty lava. Closer examination, however, does not seem to support this view, for nowhere could any sign be found of an internal flow-structure corresponding with the outside shape, and detached masses show a lenticular shape all round, not on one side only. A comparison of this volcanic rock with some of the larger sheets of quartzite, especially that opposite the Diamond Rock which is cut across by a similar transverse joint, shows that the volcanic rock and the sediment have an identical lenticular structure. There may be a 'pillow-structure' in the lavas of this district; but it is not represented by the lenticles seen in the cliff. Mr. Hill and Dr. Teall, however, think that the true pillow-structure is still recognisable.

The massive igneous rock is followed, as already mentioned, by buff much-sheared slaty igneous rock, which in the deep western corner of Great Perhaver Beach, under the old ochre mine, changes suddenly into softer dark-grey slate. In a small cave, opposite the iron stage and about 10 feet from the volcanic rock, these slates yield a thin seam or small lenticles of chert, in which Mr. Howard Fox discovered radiolaria (1 on Index Map).

The ochre mine, which was a failure, seems to have been worked in a band of weathered lava separated by slate from the main mass; but its relations are difficult to make out, and the mine is directly in the line of disturbance described below.

The foot of the cliff below the ochre mine consists of black and variously streaked slates, occasionally knotty and quartz-veined, with a few thin seams of fine-grained grit. No other seam of radiolarian chert could be found. Fallen masses, and a deposit of tufa derived from the volcanic rocks, much obscure the section. In places the slates contain small lenticles of banded mud-stone showing original bedding. Two of these lenticles, side by side, showed bedding in different directions, but both discordant with the direction of the shearing. This section was seen close to the angle of the bay and just east of the little cave where the radiolarian chert occurs. Some of the contortions at the foot of this slate cliff are perhaps due in the main to the weight of the landslips.

The cliffs and foreshore of Great Perhaver Beach exhibit some of the most puzzling sections in the district. The rocks change suddenly, and the foreshore is much obscured by fallen masses of quartzite. Great part of the sloping cliff-face also is overgrown by a tangle of bramble, ivy, and blackthorn, making it difficult either to get at the quartzite crags which rise through, or to understand their relations to the rest of the geology. Under these circumstances close attention must be paid to the various small landmarks, for otherwise it will be difficult to find some of the most interesting exposures. The landmarks are conspicuous, if the route mentioned be followed; but the map is here of comparatively little assistance.

The black slates above alluded to continue northward as far as the enormous slipped masses of veined quartzite, between which the path descends to the beach. These masses consist of smooth grey quartzite, exceptionally full of white quartz-veins, which are very conspicuous where the rock is scoured by the sea. They seem to be the same stone as that of the Carn Rock, but are not bleached; similar quartzite appears in places in a small quarry above the landslips and about 150 yards north-west of the mine-house. This part of the cliff is too much tumbled for it to be possible to ascertain the original position of the various slipped masses.

On the north of the path, where the foot of the cliff again becomes clear, siliceous brecciated slate or crush-conglomerate is seen to alternate with black slate, which contains also thin quartzite lenticles. Brecciated silicified slate of this character continues to form the base of the cliff as far as the red spring. At the top of the beach, and running parallel to the base of the cliff, appears a band of much-sheared, pale, felspathic tuff, dipping into the cliff. Possibly this reversed dip may be caused by the weight of the landslip, but it seems more probably to be a true dip connected with the curious sheared anticline which can be traced along the foreshore for several hundred yards.

All this part of the cliff is much overgrown and covered by slipped blocks of quartzite, apparently detached from some bold crags which are seen high up behind the slope. These blocks are unfossiliferous, or contain fossils very sparingly, but a few of the smaller masses show vertical annelid borings, forming the

'pipe-rock' originally discovered by C. W. Peach. Certain masses of ferruginous quartzite here contain seams full of small rounded pieces of black slate, which look like true pebbles, not brecciated fragments.

Opposite the little gully which bounds the high quartzite crags on the east, a pinnacle of rock a few yards below high-water is formed of much-sheared tuff and slate, apparently dipping at 70° seaward. Close to the cliff opposite, bedded gritty mylonite dips at 60° into the cliff.

A few yards further on a highly ferruginous spring issuing from the foot of the cliff stains the beach bright-red and cements the stones together by a deposit of tufa. This 'red spring' will be found a useful landmark. It is given out by a bed or series of lenticles of quartzite in a mass of black slate. The curved surfaces of these lenticles in place should be examined, as they explain the origin of the wonderful curved slickensides seen in the detached block further on.

Opposite the red spring, and twenty-five yards from the cliff, the band of tuff is again seen; but here it appears to be nearly vertical. It is in contact on its seaward side with a mass of much-sheared Devonian basal conglomerate, which appears to be largely composed of pebbles of this tuff. Many large blocks of this conglomerate appear at low-water a few yards further on; but they are all detached and surrounded by sand, which obscures the rock on which they rest.

The point forty yards north of the red spring shows more sandy slates and crush-breccias, with tuff at the base. Below are enormous fallen blocks of quartzite, the largest of which is beautifully slickensided, and is probably one of those described by Peach in 1871 as glaciated (see Plate 2). Immediately east of this block, bedded coarse grit with a low dip appears for a yard or two. The curved slickensides in the quartzite, and the mode in which the isolated lenticles occur in the cliff, throw great light on the general structure. Hard massive rocks, like the quartzites and some of the lavas, have been torn apart, and their corners sheared off, till they become isolated lenticles with curved faces. Smaller hard bands, like the quartz-veins, grits, and radiolarian chert, become smaller lenticles of the same character, whilst softer rocks, like the slates, have been sheared out into streaks, so as to develop a new parallel structure, though the original contorted bedding is often still recognisable.

Between the striated mass shown in Plate 2 and the half-tide block as big as a cottage, lying about 200 yards further north, the tuff forms the foot of the cliff. The cliff above is formed by siliceous slates with lenticles of quartzite, followed upwards by 50 feet of black siliceous laminated slate, with little vein-quartz or quartzite. Midway between the cliff-face and the half-tide block, ledges of coarse sandstone are seen for a few yards, dipping at 70° into the cliff. They are probably Ordovician, but are not easy to distinguish from some of the much-sheared Devonian sandstones. They may be Devonian, for near this point there is evidently a complicated inversion and overthrust.

Immediately north of the half-tide block, the cliff makes a small point, and there is a considerable development of siliceous rocks, the lower 30 feet of the cliff (all that is not overgrown) consisting of large lenticles of quartzite in black slate. This is the beginning of a large band of quartzite which is well seen in the cliff-face for about 200 yards. At the foot of this point there is a trace of the raised beach platform. At one spot, a short distance beyond, a vertical mass of quartzite forms the base of the cliff, and shows rare and obscure fossils. The fallen blocks opposite include ferruginous quartzite, rare 'pipe-rock,' and a fine-grained, dark-grey, very micaceous quartzite with rusty specks. This last generally occurs in comparatively small, flat, smooth pieces and is often full of trilobites (*see* p. 39). It also yields the best-preserved brachiopods. In this neighbourhood comparatively few of the slipped blocks belong to the granular sugary quartzite of the Carn, and fossils are exceptionally plentiful.

About midway between the half-tide block of quartzite above referred to and another half-tide island of slate, and opposite a small stream which flows through a thick bed of tall *Equisetum*, fallen blocks of quartzite show seams of fossils on the bedding planes (2 on Index Map). The quartzite is somewhat coarse-grained, and does not preserve the finer sculpture of the fossils at all well. A large amount of this material was broken up; but the fauna proved to be a poor one. *Orthis calligramma* Dalm. is very abundant; but the other fossils determined by Mr. E. T. Newton are only a *Calymene* and a *Favosites*. A large block of this material leaning against the cliff was split with wedges along the bedding-plane. The new surface is covered with fossils, and after a few years' weathering to remove the ferruginous film it may be possible to see something on it besides *Orthis calligramma*.

Some of the large fallen blocks further east show this fossiliferous rock in contact with the fine-grained iron-grey trilobite-bed, which seems to be a thin band in the quartzite series. In neither of these quartzites have the fossils been much distorted by shearing; which has shattered the rock, and has torn it into lenticles, but has not caused movement between the sand-grains. This absence of shearing or parallel structure in the fine-grained highly micaceous trilobite-bed shows that the consolidation into quartzite was complete before the shearing took place.

About 50 yards beyond the split fossiliferous mass, and just at high-water mark, a large mass of crush-conglomerate is composed of lenticles of fossiliferous limestone and granular dolomite. This mass rests on an outcrop of much-sheared gritty dolomitic limestone, dipping towards the cliff at about 60°, the grit weathering so that both dolomite grains and shear-planes are very conspicuous (3 on Index Map). The limestone fragments in the detached block reach the size of a foot or more, and seem to have been derived from more than one bed in a calcareous series. The commonest rock here is a blue limestone, full of well-preserved crinoid ossicles; but thus far not yielding anything specifically determinable. Another rock is a dull earthy

limestone, like Lias, in which was found a cephalopod, referred by Mr. Crick to *Phragmoceras*. These and an indeterminate *Favosites* were all the fossils found; but the occurrence of *Phragmoceras* shows that the rock is Silurian, not Ordovician.

As far as the half-tide island of slate opposite the Carn Rocks, the raised-beach platform and the lower part of the cliff show alternations of black slate, quartzite, and grit, with a good deal of vein quartz and rare lenticles of tuff. The island and the foreshore around it exhibit black slate and grit, striking north-east and dipping at 70° seaward. There is apparently a sharp anticline or a fault, for the rocks of the raised-beach platform above are much disturbed, nearly vertical, and show bands of fossiliferous limestone crush-conglomerate. The lower part of the cliff shows a south-easterly dip. One of the bands of crush-conglomerate is here composed of a shaly limestone or limestone-shale full of corals, the cavities of which show crystals of dolomite and tetrahedrite. Unfortunately the corals do not seem to be determinable; but they have been preserved in the Survey collection.

Jobbles Rock (the large mass below low-water mark) is a block of quartzite, apparently fallen from the Carn Rocks. The small bay north of Jobbles Rock shows highly siliceous slates interlaminated with grit, dipping at about 80° into the cliff and striking parallel with the coast. In the middle of this bay the Ordovician series ends, cut off by a fault which brings down Devonian sandstones. These sandstones will be described in Chapter IV, as north of the fault Ordovician rocks do not reappear.

On the west side of the Dodman the rocks are very similar to those on the east. This westerly section, however, is more drawn out and somewhat more accessible, and it has therefore been selected for the colour-printed diagram at the foot of the published map. It may be observed, however, that the section represents the strata as they would be seen from a distance, and does not follow the ever-varying trend of the cliff. Only in this way is it possible to make the geology intelligible, and to bring out the regularity of the dip of the divisional planes, which, however, only to a limited extent indicate the true bedding. In this region the dip is the only regular structure which can be depended on; for the rest, one is constantly disposed to abandon the attempt to work out the relations, and to call the whole cliff a hopelessly confused mass of crush-breccia, with larger or smaller lenticles, of rocks of various types and of various geological dates, but with no recognisable connection with each other.

The west side of the Dodman is very steep and bold, for the cliff cuts nearly across the strike, and there is therefore little tendency to slip. The foot of this cliff was examined by means of a boat, for most of it cannot be climbed. The rocks are singularly uniform in character, for though they must be of considerable thickness, they everywhere show the same puckered

pale grey phyllites, with almost a silvery lustre on the cleavage planes; they show no differences beyond a slightly finer or coarser grain. There would seem to be no sandy beds, and on this side of the point no band that effervesces with weak acid was found. The whole mass seems originally to have been a fine-grained silty mud. It may have contained volcanic dust; but there are no coarse fragments, and no volcanic material could be recognised under the microscope. At Dodman Point the cleavage dips south-east at about 40° or 45° ; but this angle increases to 60° towards Hemmick.

It will be found most convenient to commence the examination of this section at Hemmick Beach, which is readily accessible; but the whole of this coast needs low-tide, and preferably low-water spring tides. The upper part of the cliff is vertical and cannot be examined; but the exposures at the foot and on the foreshore are excellent, and free from the talus which so obscures Perhaver Beach. Great care must be taken, for at various points long ridges run down nearly to low-water, and these ridges, though low, are often too smooth and vertical to be climbed on their north-west face. This face often even overhangs, and one is inclined to drop the few feet on to the sand below, without realising that retreat the same way is barred.

The examination should commence with the normal Dodman rocks in the coves just east of Hemmick Beach, for here the cliff is high and the rocks at the foot are quite unweathered. They consist, as usual, of pale-grey, wrinkled, fine-grained slates, much veined with quartz, which occurs mostly nearly parallel with the dip (here 60° south-south-east). Nearly vertical strain-slip cleavage with the same strike locally cuts out this dip in a curious fashion and crumples the quartz-veins, a newer set of thin uncrumpled veins running parallel with it.

Where the cliff becomes lower, at the southern horn of Hemmick Beach, it and the ledges opposite show similar phyllite banded with red. Small faults occur, but they seem to be of no importance. Head or rubble drift occupies the valley, and destroys the continuity of the section for a few yards, but the rocks on either side of the stream are identical.

The west horn of the cove, above high-water, shows pale-grey silvery slate, darker at the sea-level; there is much quartz-veining, as on the east. As the cliff again becomes higher the ledges at its foot show banded rock of dark grey, light grey, and red. Some of the cleavage planes and cross joints show a curious honeycomb weathering (see Plate 3) not easy to account for, as the rock is not perceptibly calcareous or concretionary. Perhaps this may be due to some unrecognised organic agency.

Dodman phyllites of similar character continue as far as a small point twenty yards east of the long point which stretches nearly to low-water. This small point exhibits on its west side the curious section shown in Plate 4. The ordinary cleavage or shearing is here folded into an arch with strongly marked horizontal banding. This arch is cut by numerous close planes of strain-slip, nearly vertical. Between this section and the long

point runs a strike-fault, which, however, does nothing beyond causing a trough and small recess in the cliff.

The long point and Cadythew Rock are formed of beautifully banded rock of the Dodman type, cut more or less by vertical strain-slip. The photograph (Plate 5) shows this excellently; but the narrow vertical bands are of unusual type, though evidently closely related to those seen in Plate 4. The point, which at first seems to bar the way till half-tide, is really passable through a narrow arch up to within an hour of high-water. Immediately west of the long point will be found another slide-fault of no importance.

The small bay west of Cadythew Rock—unnamed even on the six-inch Ordnance Map—shows similar phyllites in its eastern half. A certain amount of tufa appears on the cliff-face, but it is probably derived from the volcanic rocks on the slope above.

A deep recess just before the west horn of this deep cove is reached shows an abrupt change, for a strike-fault brings Dodman phyllites against coarse felspathic much-sheared volcanic ash, of the type already mentioned as occurring at Little Perhaver. The dip is about 50°. The volcanic rock is somewhat mixed with slate in the little point west of this recess; but another small recess round the corner shows a second fault, and then comes on a more solid mass of the ash. It is possible to climb out of this bay if the tide is too high to go further; but there is no path.

We have now crossed the boundary of the Dodman rocks on either side of the point, and find that in each case the junction is probably faulted. There is nothing to suggest continuity with the other slates, and the abrupt incoming of volcanic ash and of sandy strata marks a great change in physical conditions. Rocks other than phyllite nowhere occur south-east of the boundary, and though Dodman phyllites may occur in lenticles in the confused masses of crush-breccia on the north-west, they have not been recognised, and at present we have no clue to the relationship of the two series. The Dodman rocks are more metamorphosed than the other slates; but even their relative age we cannot prove.

The next recess to that just described shows the low-hade overthrust fault illustrated in Plate 6. On the upper side of the fault, quartzite and slate underlie the volcanic ash, the continuity being broken by a later fault of twenty feet throw, which makes the cave. Out of this minor fault grows a boss of calcareous tufa, which so hides the fault that it scarcely shows in the photograph. The under side of the thrust plane shows grey banded crumpled slate, at first sight resembling that of Hemmick Beach, but soon changing into the more ordinary and variable type of Ordovician slate.

From the next point, onward to that which forms the east horn of Percunning Cove, occur ledges and cliffs of alternating pale ashy felspathic slate and grey gnarled slate, all much sheared. The long high ledge east of Percunning Cove extends to low-water, and mostly overhangs on its north-west side. Nearly till half-tide, however, it is passable through a tunnel which begins

close to the cliff on the east side and comes out on the west into Percunning Cove a little below half-tide level.

The base of the cliff at the east end of Percunning Cove shows clearly the way in which the volcanic ash and the slate are mixed near their junction, so as to appear to alternate. They are really in sheared lenticles, the ash becoming scarcer away from the main volcanic mass, and the lenticles of slate and quartzite becoming rarer as that mass is approached. This interbedded or alternating zone seems here to be about 30 or 40 feet thick, and can be particularly well studied, though a similar tearing to pieces can be traced wherever two rocks of recognisably different character come together.

Another narrow band of ash is let in between two faults, and then we reach the main mass of slates, large blocks of quartzite seen on the foreshore apparently having fallen from lenticular masses in the slate. The slate is black or dark-grey, with thin white streaks, probably volcanic, small lenticles of coarse grit, and radiolarian chert (4 on Index Map). The radiolarian chert was discovered by Mr. Howard Fox in thin masses near the ochre mine¹. One or two large isolated lenticles of quartzite occur in the slate just before Madam Bray Rock is reached, apparently coming up along an overthrust. Madam Bray Rock itself is another enormous lenticle of quartzite. West of the Rock the slates seem to become much more regularly bedded, dipping at 70°; but this appearance of regularity is only deceptive, and shows merely that the flow is no longer obstructed and rendered irregular by hard masses.

The west horn of Percunning Cove is formed by green basalt of the Perhaver Point type; but it is so much sheared up with black slate that its original relations and thickness are impossible to make out. It seems to have been a thick mass, perhaps once continuous with that of Perhaver, though the apparent thickness may be caused by overthrusting and packing.

The small bay between Percunning Cove and Black Rock is occupied by black and striped slates, like those near the ochre mine. On its west side these slates contain scattered large lenticles of quartzite, which gradually give place to the more massive quartzite of Black Rock. As is always the case in the neighbourhood of large masses of quartzite, the dips have become very irregular.

In the recess immediately east of Black Rock an adit has been driven into black slates with lenticles of quartzite. The water that issues from it deposits much limonite and also tufa. It seems to correspond in position with the red spring on Perhaver Beach. The adit appears to have been driven along the spring, in search of iron or ochre, for there is no sign of any lode, and nothing has been worked. Above this red spring will be found a disused path, leading to the top of the cliff immediately above Black Rock.

Black Rock itself consists of massive white or grey quartzite, like that of Perhaver, the black colour being due to the growth

¹ *Trans. R. Geol. Soc. Cornwall*, vol. xii., 1896, p. 47.

of lichen. The rock seems to be an enormous lenticle several hundred yards long. Another similar lenticle forms the bold crag known as Clitter's Rock on the hill above. It is impossible to say what was the original thickness of the quartzite, but no one mass can be seen to exceed 20 or 30 feet. There may be several bands divided by slate partings, or the thicker masses may be due to the packing of one seam of moderate thickness. Some of this quartzite is much brecciated, and has been re-cemented by silica; a hand specimen placed in the Museum illustrates well this passage of the quartzite into a breccia.

Immediately west of Black Rock comes a thick mass of pale-coloured felspathic ash, like those already described. Under the Coastguard Watch House, and opposite Attimiday Rock are found grey ashy slates; but most of this part of the cliff is difficult of access and is best visited by boat.

Immediately west of the Watch House a thick mass of the felspathic ash forms a bold ridge, which is continued seaward in Greeb Point. This mass is so thick and solid, and the cliff is so high, that it was thought that here at any rate it might be possible to obtain better material for petrological examination. A specimen of the rock was therefore taken from the Point at the level of low-water spring-tide; but the material was no better preserved than elsewhere, and this appears to indicate that the alteration the ash has undergone was of Palæozoic date.

West of Greeb Point, in Lambsowden Cove, comes dark ashy slate, followed by a large lenticle of quartzite. Next follows more dark, probably ashy, slate, in which appear just east of the valley a lenticle of lava, and some of quartzite.

The cliff and foreshore at Lambsowden Beach are mainly grey slate. The bay is difficult of access and is best visited by boat. The Black Rock, which forms the western horn of Lambsowden Beach, exhibits ashy slate, with large lenticles of quartzite, ash, and basalt. Then follows a massive close-grained quartzite, like that of Perhaver, forming a bold point (not named on the map). The cliffs at this point exhibit excellently the mode of occurrence of the hard quartzite, which forms large lenticles, usually two or three times as long as they are thick. These lenticles are piled one upon another, with slate between, so that they form a bold ridge on the grassy slope above the cliff, where also an exceptionally thick mass of solid quartzite occurs. If, however, we follow this feature up the slope it is found the quartzite dies out entirely within 400 yards. In the cliff the quartzite just described is followed by black slates, also dipping south-east at about 45° .

The next section of the cliff, though accessible from above, is perhaps more conveniently approached from Porthluney at low-water; but as the foreshore is barely passable up to half-tide and the scrambling is rough, we will continue the description in the same direction.

Catasuent Cove is the deep recess, with gravelly beach and narrow entrance between rocky ledges, which lies immediately west of the bold quartzite crags so conspicuous on the slope

above the cliff. Follow the east side of the quartzite downward till a low earthy cliff is reached, from which it is easy to descend to the raised beach platform below. Then turn to the west along the platform till the low vertical ridge which bounds Catasuent Cove is reached, and down this a ledge passes. This track can be used for nearly three hours before and after low-water; but the higher part of the ridge overhangs and is unclimbable. It needs an exceptionally calm day for boats to venture into this cove (5 on Index Map, p. 11).

On descending to the beach at Catasuent Cove and looking back at the vertical face just passed, one sees that this cliff of 50 or 100 feet in height is practically composed of crush-breccia. Much of this breccia is such as we have noted in many places, *i.e.*, it seems to be composed mainly of rocks in the immediate neighbourhood. There are also many fragments of a soft pale-grey striped highly micaceous rock suggestive of the phyllite of the Dodman, though the fragments are more micaceous and contain thin seams of grit. An examination of the quartzite and vein-quartz fragments shows that the rock is a crush-breccia, not a true conglomerate. In the middle of this vertical face, and accessible where talus has fallen from the slope above, there is a belt, some 20 or 30 feet in thickness, of crush-breccia of different composition, containing many blocks of fossiliferous Silurian limestone of varying character.¹ This belt of crush-breccia seems to mark the position of one of the bigger overthrusts.

The limestone masses vary considerably in character, and are apparently derived from a whole series of beds, not from one thin band; they are all quite unlike the sparingly fossiliferous limestone of Veryan, and are much less crushed and sheared internally. One large lenticle measuring nearly 4 feet by 1½ feet thick consisted of dark-blue solid crystalline limestone, looking like carboniferous limestone and largely composed of crinoid-fragments. Other more earthy masses were granular and dolomitic, and one of these contained several badly preserved specimens of *Orthoceras*, thought by Mr. Crick to be an Upper Silurian form. One block of dull-black earthy limestone was full of a small *Leptaena*, referred doubtfully to *L. scissa* Salter by Dr. Matley, and it also contained a second larger species. One mass, found by Mr. Fearnside when he visited the cove with me, and presented to the Survey, contained great part of a large crinoid, which Dr. Bather has referred to *Scyphocrinus*, an upper Silurian genus not previously found in Britain, but characteristic of Lower Wenlockian strata in Bohemia.² Besides these there are undetermined corals and *Fenestella*; but the shaly limestones with *Fenestella* are here much scarcer than they are in the band near Porthluney. Fossils are only well seen on the weathered faces, and now that these are removed it may

¹ Fossils were first noticed in the limestone of Catasuent and Porthluney about the year 1846 by C. W. Peach.

² F. A. Bather, 'The Discovery in West Cornwall of a Silurian Crinoid characteristic of Bohemia,' *Trans. R. Geol. Soc. Cornwall*, vol. xiii., pt. III., 1907, p. 192.

be some years before a fresh supply is obtainable; the more crystalline blocks however clearly show that they are made up of broken crinoids. All the specimens are now in the Survey collection.

The rest of Catasuent Cove is occupied by black slate with enormous lenticles of quartzite, all much sheared and brecciated. The rocks of this part of the coast would probably all be called crush-breccia, were it not for the clear distinction between this crush-breccia of local origin and the crush-breccia composed of fragments not belonging to this area, and in many cases not resembling any rocks known in Cornwall.

The west horn of Catasuent Cove is a confused mass of hard slate with lenticles of quartzite and green basalt; it shows fine examples of lenticular shearing. Diamond Rock, the large rock only accessible at extreme low-water, is a large fossiliferous quartzite lenticle, in a line with those forming the west horn of the next cove (6 on Index Map). This small cove is mainly black slate with lenticles of tuff and lava. On the floor of the cove will be seen some exceedingly fine blocks of brecciated quartzite cemented by silica and traversed by later, straight quartz-veins. These breccias are worth close examination, for at first sight they seem to resemble the basal Devonian conglomerate which is seen at Porthluney. The Diamond Rock crush-breccia, however, is composed entirely of quartzite, and though the fragments have been somewhat rounded at the corners during the movement, they are not true pebbles. The smooth wave-worn surface of this rock has more the appearance of an irregular mosaic than of a pudding stone.

Next follows a thick mass of quartzite, with many fallen blocks, which give very rough scrambling and are not passable after half tide. The quartzite may be a repetition of the mass east of Catasuent Cove; but it is too much sheared for anything to be made out as to its relations. In this quartzite C. W. Peach many years since found *Orthis*, and in the old collection of the Geological Survey is a specimen of the peculiar fine-ribbed variety of *O. porcata* found also in Perhaver Quarry.

When this point is rounded we enter Porthluney Cove and find a sandy flat at low-tide. The slates are hard and often gritty, are banded black, grey, and red on the foreshore, and exhibit beautifully the shear-structure (see Plate 7). On following these beds into the cove we come to a small dark cave, and this marks the exact position of the second, or Porthluney, overthrust (7 on Index Map). On the foreshore and in the ledges, striking straight to this cave, there is a conspicuous mass of reddish crush-breccia, and associated with it are found the masses of fossiliferous limestone first noticed by C. W. Peach, and more fully described by Messrs. Upfield Green and C. D. Sherborn.¹ The massive limestone, judging by the cephalopoda found by Mr. Green and determined by Mr. Crick, which are comparable with *Actinoceras baccatum* H. Woodw., and *Barrandeoceras holtianum* (Blake), are probably of Ludlow age.² There are

¹ *Geol. Mag.*, 1904, p. 289; 1906, p. 33.

² These fossils are now in the British Museum (Natural History).

also masses of limestone shale and shaly limestone, from which Messrs. Green and Sherborn record the following species, determined by themselves and presented to the Survey collection:—

Ptilodictya lanceolata Lonsd.

Fenestella assimilis Lonsd.

Fenestella cf. *B. M.*, D 571, from Wenlockian of Dudley.

Fenestella sp.

Millepora cf. *repens* (L.).

Monticuliporid, ramifying through the whole mass of the lenticle.

Rhynchotrete cuneata (Dalm.).

Amphicelia striata (Sow.).

Pterinea sp.

These seem to be of Wenlock age.

On the west side of this thrust-plane black and red banded slates again occur; but they are associated with so much coarse grit that, were it not for the occurrence of scattered lenticles of quartzite and of tuff, they might be taken for Devonian; indeed it is quite possible that lenticles of Devonian grit may be included in this crush-breccia.

The next projecting point is composed of buff or pale-coloured igneous rock, much sheared and brecciated at its junction with the slate, and also a good deal decomposed. A specimen obtained at extreme low-water shows, however, that it passes downward into a green rock like that of Perhaver. This igneous rock, with some bands of slate and crush-breccia, continues nearly as far as the Porthluney stream; but close to the stream it rests, apparently by overthrusting, on true conglomerate, associated with grey dull earthy slate of the Devonian type. These latter rocks will be again referred to in Chapter V.

The wide sandy beach of Porthluney seems to mark the position of a syncline of these soft Devonian slates, for on the opposite horn of the bay they reappear, with more grit, and are followed by a thin band of the basal conglomerate, resting on the older slates. This junction cuts obliquely across the horn. This conglomerate is succeeded westward by dark Ordovician slate, much contorted and sheared, and containing quartzite lenticles. These rocks must contain a good deal of lime, for tufa is deposited by the small springs. Then comes a sudden transition to a belt of grey sandstone and coarse grit, apparently of Devonian age, with perhaps fault-junctions on either side.

At Long Point green volcanic rock comes on again, and between two bands of this rock we find a narrow mass of sandy slate, sandstone, and crush-breccia, having a true conglomeratic base in contact with the lava on either side. This is evidently a syncline of the basal Devonian rocks, so sharply infolded that the two sides are parallel and the mass appears as a dyke.

The cliffs between this point and Portholland call for no remark, except that their massive grits and sandy slates resemble the Devonian slates between Great Perhaver and Mevagissey, though that they are far more sheared. Here the section printed at the foot of the map ends.

For about a mile and a half the altered trend of the coast makes it nearly coincide with the strike of the rocks, and only sandy Devonian strata are to be seen. Then, at Carn Pednathan, the crushing becomes more violent, and we seem again to meet with the disturbed and overthrust belts which passed out to sea at Catasuent and Porthluney.

The re-appearance of Ordovician rocks at Carn Pednathan, Caragloose Point, and Hartriza Point is marked by a series of sections, all of which show slate, conglomerate, and basalt inverted over the basal Devonian conglomerate. There is a great deal of shearing and disturbance, and much of the rock might almost be described as a mylonite, but apparently there is no faulting of any importance, and the junction though inverted is a normal unconformable one.

The sections on either side of Portloe are similar, and all show inversion; but they suggest also that this inversion is merely the disturbance in close proximity to an important overthrust. Immediately south of the village, near the cliff edge, will be seen two large masses of Ordovician quartzite, one of which forms the bold crag known as the Cuckoo Rock. These masses rest immediately on the sandy Devonian slates, with no conglomerate between, though the conglomerate is well represented close by, at Jacka Point.

The position of these two masses of quartzite seemed quite inexplicable, till it was realised that they are close to a line which connects the strange thrust-plane of Porthluney with the equally strange thrust which cuts off the Blouth, next to be described. These outliers of Ordovician quartzite are separated by a thrust-plane from the Devonian floor below, and the thrust is of such low hade that it probably strikes the sea a quarter of a mile or more away, without touching the cliff or foreshore below (see Fig. 2). In fact this thrust has much the same hade as that we see at Parc Caragloose Cove, where the angle is a good deal lower than at Porthluney and Catasuent.

Portloe Cove itself exhibits much-sheared conglomerate in the points on either side and on the floor of the cove. This conglomerate at Portloe Point is followed (in inverted order) by a mass of basalt, which clings to the cliff face. Possibly this Point is actually crossed by the fault just described, for Mr. Howard Fox speaking of it mentions that "beds of chert, interbedded with more or less decomposed mudstone and shale, are found in the greenstone tuff or breccia of the district (the 'trappean conglomerate' of De la Beche). The bands of chert vary from half an inch to six inches in thickness and extend over a space twenty yards in length by seven yards in extreme width, parallel with, and to the south-east of, a fault running N.E. and S.W. about high-water mark"¹ (8 on Index Map).

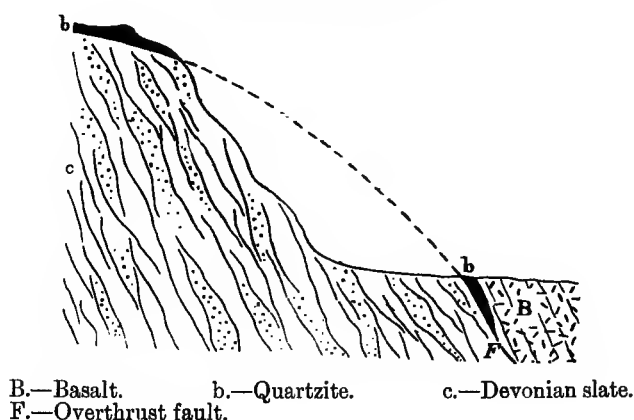
The Zawn, just behind Jacka Point and close to Portloe, shows another excellent exposure not easy to interpret. The tip of the Point is formed by shattered, brecciated, and much-sheared

¹ *Trans. R. Geol. Soc. Cornwall*, vol. xii., 1896, p. 47.

basalt. This is followed, in inverted order, by a thick mass, 30 or 40 feet at least, of coarse pebbly conglomerate, largely made up of the basalt. This section will again be referred to in a later chapter, for it is probably the best exposure of the junction between Upper and Lower Palæozoic rocks in the district. A few yards below the conglomerate, is seen a thrust-fault, along which appears a narrow belt of mylonite, of quartzite and Ordovician slate, the rocks on either side being Devonian. If this is the big overthrust, it is unusually narrow; it would, however, explain the outliers above in the way shown in the diagram (Fig. 2).

The Straythe cuts back into the softer Devonian rocks behind the fault—in fact, on this part of the coast each of the headlands is formed by Ordovician basalts and each bay by the newer strata. The fault may pass through the basalt of Manare Point, or perhaps only a branch of it does so; at any rate it

FIG. 2.—DIAGRAM SECTION TO EXPLAIN QUARTZITE OUTLIER OF CUCKOO ROCK.



does not bring in any of the far-transported masses. But directly Parc Caragloose Cove is reached we meet with a big overthrust, and a mass of crush-breccia of the Catasuent type, with transported masses of fossiliferous limestone (9 on Index Map).

As already mentioned, the Straythe shows sandy Devonian slates. The Blouth is an enormous mass, 250 feet in height, of coarse-grained basalt in thick lenticles, perhaps packed and repeated by thrusting, for there is no clear evidence of different sheets. Between the basalt and the Devonian slates occurs a band about sixty yards wide in Parc Caragloose Cove, consisting of Ordovician slate, much brecciated and cut off on either side by overthrust faults. This band contains scattered lenticles of quartzite and larger masses of grit, probably Ordovician. In the middle of the Cove a crush-breccia containing blocks of fossiliferous limestone occurs, as at Catasuent. This is followed

by a narrow band of quartzite, cut off on the north by a clearly shown fault, which drives the quartzite north-westward over a crush-breccia of Devonian grit and slate.

The faulted band just mentioned passes behind the hill, to reappear on the west side of Blouth Point, in Kiberick Cove. It also cuts off Nare Head, finally passing out to sea near Malmanare Point. The complication is so great that it will be most convenient here to confine our attention to this thrust-plane, leaving the fuller description of the igneous rocks for a later chapter.

Though blocks of fossiliferous limestone were noticed in Parc Caragloose Cove, the other rocks in the belt of crush-breccia seem to be of local origin, though the want of good foreshore sections and the limited exposure in the cliff may have caused others to be overlooked; this section needs closer examination. Where the thrust-plane reappears in Kiberick Cove, however, it runs for a quarter of a mile along the shore, and this is by far the best place on the coast to study the disturbance. As Kiberick Cove can only be approached by the road from Pennare Wartha and Pennare Wallas, it will be most convenient to speak of the exposures in the order they are met with, for the road before reaching the Cove crosses the disturbed belt at its widest point.

After leaving the farm buildings of Pennare Wallas on the right hand, we come to a quarry on the same side, just before the path to Nare Head is given off. This quarry is in Devonian grit or sandstone of the ordinary type. A few yards further on, by the side of the path to Nare Head, is another quarry, in much-decayed, coarse-grained gabbro, and we seem to have crossed the thrust-plane. The gabbro is again seen by the side of the path to the beach, and is sounder; from this point a specimen was taken. It is also thrown up by rabbits about 200 yards south of the path, so that there must be a considerable mass of it.

On the north side of the road to the beach the outcrop of the thrust-plane seems to make a very curious curve, for, less than 100 yards east of the quarry in Devonian sandstone, chert is seen, and a little distance away, near a small spring, is a crag of massive black chert, of peculiar character (10 on Index Map). It contains radiolaria, and may be the Vryan chert; but it is more solid and massive than any of the known sections of that chert, in fact its appearance was so peculiar that it was at first thought to be a metamorphosed graptolitic black mud-stone. No graptolites could be found.

Still further east, and about 400 yards east-north-east of the quarry in Devonian sandstone, there is another isolated crag, consisting of Ordovician quartzite; but both these exposures are in the middle of pasture and nothing can be said as to their exact relations. This pasture forms a curious amphitheatre, bounded by a low inland cliff of sandstone, and the rest of its floor appears also to be sandstone. The whole mass at some distant date seems to have subsided; but the subsidence

does not correspond with the thrust-plane. To this subsidence, rather than to the overthrusting, should probably be referred the shattered character of some of the Devonian sections seen above the beach, for the mass is full of still-open fissures.

On reaching the shore it is best to turn to the right, so as to start the examination with the massive igneous rock which forms Nare Head. A specimen of this rock, taken about 500 yards south of the path and close to the Horse Rock, is greatly brecciated. About 300 yards south of the path we cross a fault which divides the basalt from brecciated Devonian sandstone and slate; but this fault, though it cuts out the basement conglomerate, does not seem to be of much importance—it may be a spur from the main overthrust. On the foreshore, just north of the point where the path reaches the beach, there are some blocks of the conglomerate; but their relations to the other strata cannot be made out. Above is a cliff of grey flaggy slate and sandstone, of Devonian type, and in the upper inaccessible part of this cliff is a band of crush-breccia.

About 100 yards along the shore to the north-east a belt of crush-breccia 25 yards wide (perhaps thirty or forty feet thick) appears, and then Devonian slate and sandstone come on again. The base of this crush is a band of whitish much-sheared steatitic material, with small lumps of gabbro. Then follows a lenticle of Ordovician quartzite. Ten feet from the base comes a lenticle of crush-breccia of soft whitish earthy limestone with *Orthoceras*, a brachiopod, crinoid ossicles, *Fenestella*, and a trilobite. This lenticle, entirely composed of limestone, is over ten yards long and about five feet thick (11 on Index Map). The limestone is an earthy rock, probably of Ludlow or Wenlock age, and is quite unlike the hard crystalline Ordovician limestone found near Gidleywell. Next follows a thin lenticle of quartzite, which towards the north rests immediately on the basal steatite. The course of the fault is then hidden under the sand of the foreshore; but in the middle of the bay rises a large isolated rock of serpentine, like that of the Lizard. The rock is about twenty feet high, and is apparently the last relic of a large lenticle. Other rocks closely adjoining consist merely of Devonian grit, so that this mass of serpentine seems to be touching the northern or upper limit of the faulted belt.

The fault seems here to curve inland again, to join a fault seen in the cliff a short distance west of Blouth Point. This fault, running north and south and dipping east, shows in the cliff a mass of fault-breccia, containing a lenticle of much decayed gabbro and a paste of steatite and calcite. East of this is some Ordovician black slate and quartzite, also in the band of crushed rock. Then massive basalt, like that of Nare Head in thick lenticles dipping south-east, is entered, and this forms part of Blouth Point.

The band of overthrusting undoubtedly passes behind Nare Head and comes out near Malmanare Point; but on that side of the Head it seems to have split up into several planes of over

thrust, along none of which can rocks like those of the Lizard, or limestones of Upper Silurian type, be found.

On the west side of Nare Head the altered trend of the coast causes the cliff to cut the strata almost at right angles, and the alternations are therefore very rapid. The lenticular structure in the basalt is finely exhibited in this cliff, which is about 270 feet in height and exhibits sections very like that illustrated in the photograph of Perhaver (Plate 1).

The outlying Gull Rock may be either an independent mass or the same sheet repeated by faulting. Thanks to Mr. Howard Fox, with whom I was able to visit this rock in a tug, a landing was made on the north-west side. The Rock is mainly composed of massive greenish basalt, dipping south-east; but the north-west face shows purplish-black slate dipping under the basalt, and alternating with much-sheared igneous rock. As Devonian basal conglomerate does not occur, there is nothing to show which way up this section should be read.

We will now resume the examination of the mainland coast at Malmanare Point, which is composed of a greenish basalt very like that of Perhaver, but more brecciated. Travelling westward, the next rock met with is a narrow belt of black Ordovician slate much crushed. Then follows a band of basalt, apparently folded into the sandstone, but connected with the main mass on the hill above. The sandy slate and sandstone which come next are of Devonian age; but their relation to the basalt is obscure, though the junction is probably faulted. On the west this rock has a good conglomeratic base, well seen on the foreshore beneath the eastern horn of Mallet's Cove, where it rests on sheared limestone and black slate, of the Vryan type. These Ordovician rocks only occupy the eastern side of this small cove, being cut out on the west by a thrust-plane, which has driven them over grey sandy slate and grit of Devonian age, seen in the western part of Mallet's Cove and in Tregagles Hole. The Devonian slate is much crushed, and ends again on the east side of Paradoe Cove in a mass of much-sheared coarse basement conglomerate.

The fault in Mallet's Cove may be the continuation of the conspicuous disturbance at Kiberick Cove; for in both cases the rocks on either side of the thrust are very similar, the singularity lying in the astonishing mixture of rocks caught up in the narrow belt of crush-breccia in Kiberick Cove.

Beyond the conglomerate of Paradoe Cove and touching it unconformably is black Ordovician slate with traces of quartzite. Then follow sheared limestone and calcareous slate, like the rocks of Gidleywell. Pennarin Point is composed of much-sheared igneous rock, in a comparatively narrow band apparently unconnected with the large mass of Nare Head. This rock seems to come up as the nose of an anticline, for it is followed on the west by sheared limestone and calcareous slate identical with that on the east—or it may be a sill intruded into the middle of these calcareous strata; unfortunately the shearing and alteration are too great to allow of any study of contact alteration. Next comes

black slate, striking due north and south, as do all the strata for about half a mile on this part of the coast.

The conspicuous ridge of quartzite near Carne strikes due south from the quarry¹ to the coast, and in the cliff is seen to dip at an angle of about 20° towards the east, the dips now becoming much lower as we recede from the area of crush. The fossiliferous quartzite is sheared into lenticles, divided by black slate, the total thickness seen in the cliff being about 30 feet altogether (12 on Index Map). The base of the quartzite nearly coincides with a thrust-plane, though on the foreshore a few feet of black slate come in between. This overthrust, which is illustrated by a photograph in the Survey collection, taken by Mr. T. C. Hall, does not seem to be directly connected with the big thrust already described, though it runs parallel with it. The outcrop passes northward to Carne Beacon and then bends to the north-east; but whether the thrust has died out, or the junction has become a normal one, is not clear. On the coast the thrust has the effect of driving the quartzite over a series of sandy slates and sheared sandstones, much brecciated and veined. These are followed westward by coarse sandstones and non-calcareous slates, cut off on the west by strike-faults.

The exact position of the sandy strata just described is not quite satisfactorily made out. They are Lower Palæozoic, not Devonian, though they are somewhat like the Devonian grits. They mark also the disappearance of the quartzites and the incoming of a series of different lithological character. The only strata resembling them in the area to the east are the grey sandy shales and sandstones which occur near the red spring on Perhaver Beach (see p. 14); but there also the relations to the surrounding rocks are somewhat obscure.

On crossing the fault already mentioned as the westward boundary of these sandstones south of Vryan, we notice on the foreshore a narrow belt of dark-coloured calcareous slate, with a four-foot band of limestone. This is the commencement of the Vryan limestones. Then occur two more strike-faults, bringing in between them another narrow band of coarse non-calcareous sandstone and sandy slate; this contains bands of crush-breccia; but the true bedding is now becoming conspicuous. After this alternation, and beyond the last of these three faults, we lose the non-calcareous sandstones and definitely enter the main mass of the Vryan calcareous series.

Close to the edge of the one-inch map will be found a narrow belt of black slate and radiolarian chert. This is followed, just at the limit of our area, by the limestone of Gidleywell (13 on Index Map). Here the foreshore shows alternations of sheared blue limestone and black slate full of calcite-veins. The limestones are in folded and crumpled beds, the thickest reaching only three feet. The rock is very hard and crystalline, but too impure for

¹ While this Memoir was passing through the press Mr. Howard Fox obtained from this quarry the body and tail of a large *Calymene*, which will be figured and described by Mr. Philip Lake.

burning. It contains fragments of crinoid ossicles and now and then a complete ossicle. Unfortunately none of the Vryan limestones have yielded characteristic fossils, the only others found being some small tubes of unknown affinities, recorded by Mr. Howard Fox and Dr. G. J. Hinde.¹

Though the remainder of Gerrans Bay is outside the area included in the Mevagissey map, yet it will be necessary here briefly to allude to its cliffs as far west as Pendower, for the strike of the rocks is such that the same strata run inland into the area with which this Memoir deals, and the inland exposures cannot be understood unless they are compared with the clearer ones on the coast.

For a short distance west of Gidleywell the rocks consist of more or less calcareous slates with thin bands of limestone. Then, nearly to Pendower, follow well-laminated soft calcareous slates, often full of manganese, which here and there takes the form of thin seams of carbonate. These rocks contain also occasional thin limestones, as well as narrow seams of coarse felspathic grit, usually quite soft and little consolidated. One of their most striking characteristics, however, is the occurrence in them of a mass of thin-bedded radiolarian chert 10 feet or so in thickness, passing into and alternating with thin laminae of slate.² Thus far this chert has yielded no fossils by which we can fix its age, though it is generally considered to be equivalent to the chert of Mullion Island. The radiolarian chert, being quite insoluble, is readily traced in the ploughed fields inland, and is therefore a very important horizon. It is probably on a somewhat different horizon from the thin cherts found by Mr. Howard Fox on several parts of the coast to the east, for the accompanying slates do not seem to correspond.

Close to the stream at Pendower, which is about half a mile beyond the border of the map, the calcareous and manganiferous slates just described give place to dark grey slates alternating with thin bands of hard grit, and in these it is only possible here and there to find any seam which will effervesce with weak acid. The change is a very striking one. These Portscatho grits when once reached form a most monotonous area, and there is little to say about them, though they spread over several square miles between Vryan and Tregoney. Thus far they have proved entirely unfossiliferous. They are more fully described, by Mr. J. B. Hill, in the Memoir on Sheet 352, in which area they are far better represented.³

Before leaving the coast there is one other piece of evidence that should be referred to. It will be remembered that the big overthrust was followed westward till it was lost under the sea near Nare Head. It is curious to observe, therefore, that

¹ 'Notes on Vryan and other Limestones associated with Radiolarian Cherts in South Cornwall.' *Trans. R. Geol. Soc. Cornwall*, vol. xii., 1898, p. 179.

² Howard Fox, 'The Radiolarian Cherts of Cornwall.' *Ibid.* vol. xii., 1896, p. 39.

³ 'Geology of Falmouth and Truro.' *Mem. Geol. Survey.*

though the Lizard rocks so conspicuous in Kiberick Cove do not occur in the cliff on the west side of Nare Head, yet from Gidleywell westward to beyond Pendower quantities of pebbles of gabbro will be found on the beach. These pebbles seem to have come from destroyed masses of rock in Gerrans Bay; but it is noticeable that the pebbles do not belong to the variety of gabbro found near Pennare. They belong to a peculiar gabbro drawn out into long rods, and this also can be matched in the Lizard. The pebbles are so much sounder than any gabbro in Kiberick Cove that it is possible they may have come in some other way, perhaps transported as erratics during the Glacial Epoch. It is noticable, however, that they seem to be confined to a very limited tract near Pendower, and do not pass round Nare Head. This extremely limited dispersal is against glacial transport, and points to a local origin.

CHAPTER III.

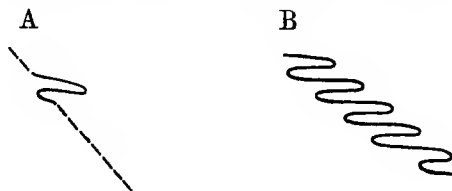
LOWER PALÆOZOIC ROCKS.

INLAND EXTENSION AND GENERAL STRUCTURE.

An examination of the Map will show that near the coast between Gorran Haven and Veryan the thrusting from the south-east has been so vigorous as to close up all folds, thus making all the rocks strike nearly in the same direction, that is to say about north-east and south-west. Yet in the same area there is clear evidence of a marked unconformity between the Upper and Lower Palæozoic rocks. As we recede from this belt of extreme packing, folding, and overthrusting, we enter a region in which the Devonian rocks are comparatively little affected, though they still show sharp folding and shearing, roughly parallel to the overthrusts we have been describing. That is to say the axes of the folds still run about west-south-west; but the base of the Devonian strata gradually takes on the normal east and west strike, dominant throughout Cornwall and Devon; it runs west-north-west near Tregoney, changing to due west a short distance beyond Tregoney, and outside our area.

As regards the line engraved for this unconformable base of the Devonian rocks, it should be said that the exact boundary is often not easy to follow in the plateau near Tregoney, for the sandy basal Devonian and the sandy Portscatho rocks there happen to come together. They are a good deal alike; and in the absence of good sections, or unless we find the narrow bands of conglomerate, the exact line may easily be missed. Under these circumstances, where in doubt the line has been generalised, making the engraved boundary a straight broken one as in A, instead of drawing hypothetical folds as in B (Fig. 3). The zig-zag

FIG. 3.—DIAGRAM SECTION TO ILLUSTRATE THE RELATION OF THE MINOR FOLDS TO THE GENERAL STRIKE.



line no doubt better represents the true structure, though all its details may be wrong. Small folds or ripples are here riding on a wide anticline which has a different axis. This anticline will again be referred to in Chapter IV.

The opening out of the newer folds in the Tregoney area allows us to see clearly that the Lower Palæozoic rocks have an earlier strike, quite independent of and passing unconformably below the Devonian rocks. This ancient strike is everywhere south-westerly, and in passing from south-east to north-west, though there is a certain amount of repetition, we pass over successive belts of different lithological character, and obviously of different age. Leaving out for the moment the exceptional and isolated faulted mass of the Dodman, we seem to cross older and older rocks as we travel towards the north-west, towards the Mylor slates around Truro.

The grounds on which this succession, rather than the inverse order, is considered the most probable are not altogether satisfactory; but such as they are they suggest that the fossiliferous quartzites of Gorran are near the top of the lower Palæozoic rocks of the area. Until we succeed in finding fossils of known date on a second horizon there must remain this doubt. At present the Veryan limestone series with its associated radiolarian cherts has yielded nothing characteristic, though they have been carefully searched both by Mr. Howard Fox and by the Survey. The fossiliferous Upper Silurian limestones occur, unfortunately, only as detached masses in a belt of crush-breccia which yield also all sorts of rocks of more ancient type, perhaps Archæan. The evidence for the true succession practically amounts to this: The overthrust is from the south-west, and brings up masses of Upper Silurian rock of types otherwise quite unknown in Cornwall. These Upper Silurian rocks seem therefore to lie under the English Channel, and would appear still further south to be associated with rocks of the Lizard type, which also appear along the thrust-plane. If this is the correct interpretation of the phenomena, it follows that the Upper Silurian rocks are probably most nearly allied to the rocks with which this thrust has generally brought them in contact, that is to say they are nearest in age to the Gorran quartzites and least related to the Portscatho Beds. Of course the existence of a ridge of Archæan rocks (represented by the Eddystone gneiss) further south does not affect the question, as there is probably a complete unconformity between these and the newer deposits. Unfortunately the anomalous mass of the Dodman phyllites does not seem to fit in anywhere, except possibly as an overthrust mass, perhaps of the age of the Mylor slates, but more altered than these fine-grained sediments usually are. The Mylor slates follow the Falmouth series, which come next below the Portscatho Grits.

Opinion has fluctuated more than once as to the correct reading of the succession of the rocks in West Cornwall, but now Mr. Hill and I think that the balance of evidence is in favour of this interpretation, though we can make no suggestion as to the true geological position of the lower strata.¹

¹ See 'Summary of Progress of the Geol. Survey for 1905,' pp. 24, 25.
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Though the strata on the coast are so confused, this confusion rapidly becomes less as we recede from the belt of great overthrusting and packing, which happens nearly to coincide with the cliff between Perhaver Beach and Carne, near Veryan. Thus in mapping the inland geology it was found that the Lower Palæozoic rocks fall into several roughly parallel belts, the strike of which is north-east and south-west.

First come the Dodman phyllites, which may be an overthrust mass of very ancient rocks, as we have already suggested. Its boundary has the normal trend.

Next comes a belt of black slightly calcareous slate, with sandy bands, fossiliferous hard quartzites, and rare thin bands of radiolarian chert. In this series occur most of the pillow-lavas and all the bands of white felspathic ash. These rocks extend from Gorran Haven and Perhaver Beach to Nare Head and Carne, unfortunately always being found within the zone of great movement and crushing. This excessive disturbance makes it impossible to say what is the detailed succession, for constant overthrusting brings each bed in turn into contact with every other. It can only be suggested that if the rule of a general downward succession toward the north-west applies in any degree to the details, then the felspathic ashes, which are confined to the area in the parish of St. Goran, should be near the top of the series. The quartzites and sandy strata follow; for though they seem to be hopelessly mixed with the felspathic ashes in the most disturbed area, yet to the north-west they occupy an independent belt, which runs from the crags of Great Carn, above Perhaver Beach to the quartzite ridge of Carne, near Veryan. It is unfortunate that the north-western limit of the quartzite series is everywhere either an overthrust fault, or is hidden by the overlap of the Devonian conglomerate. The greenstones would seem to occur on at least two horizons, so that they do not help us to understand the succession; they will be described in a separate chapter on the igneous rocks (Chap. V).

The felspathic ash and the quartzite groups are so intermixed, that it will be most convenient to trace their inland distribution together, taking afterwards the calcareous slates of Veryan. We will commence with the neighbourhood of Gorran Haven.

Along the path which leads from Gorran Haven, past the Coastguard Station northward into the Mevagissey road, the first thing that will be observed is some large blocks of quartzite by the road-side. These particular blocks seem to have travelled down the valley; but where similar groups occur on the level plateau they indicate the presence of large lenticles, such as are seen in the cliff. Just above the Coastguard Station the boundary of the pillow-lava crosses the road, and the exposure shows how exceedingly decayed this rock is at the surface. The greenstone forms an exceptionally rich ferruginous soil, but otherwise ploughed fields often show no other indication of the presence of igneous rocks below. This makes the recognition of these irregular lenticles very difficult inland, and there are probably more of them than have been mapped. This particular lenticle,

though forming such a great and conspicuous mass at Great Perhaver Point, has apparently narrowed to a third of its width where the road to Trewollock crosses it, and no trace of it can be found in the main high-road to Church Town.

A quarter of a mile north of the Coastguard Station the path turns to the left to Trewollock; but at this point a faint track will be seen crossing the meadow to the right, towards Perhaver Great Carn. If this track is followed it leads through a gate to a small quarry in bedded sandstone and quartzite, of a character unlike any seen elsewhere, though small fallen masses may occur on the shore below. For distinction this quarry will be called the Perhaver Quarry (14 on Index Map). The main part of the rock is a bedded felspathic grit, certain bands of which, apparently more purely siliceous, have become quartzites. Unfortunately this comparatively soft rock is a good deal sheared, and it is not easy to obtain good fossils, especially as the section is a good deal over-grown and hidden by talus. Fossils are particularly abundant in a band of moderate hardness near the middle of the pit; a few, perhaps better preserved, occur in a fine-grained quartzite on the right.

This quarry yields the common fossil of the Gorran quartzites, *Orthis calligramma* Dalm.; but the most abundant and striking form is a beautifully sculptured larger and flatter species of *Orthis*, which Dr. Matley refers with considerable doubt to a finely-ribbed variety of *O. porcata*—it is a well marked and characteristic form, of which we have now several fair specimens. The other fossils here found are not sufficiently well-preserved for determination; they consist of small (or young) *Orthis*, the tail of a trilobite, probably *Calymene*, and a small fragment of *Conularia*. The matrix is too coarse-grained for the preservation of the sculpture on the smaller fossils, and leaving out of account *Orthis calligramma*, which apparently has a very wide range in time, the only species of value for correlation is the finely-ribbed *Orthis*, which seems to be a form unknown elsewhere. This quarry is worth further search.

It is impossible to make out the relations of the different quartzite bands in the obscure ground around Perhaver. The quarry just described shows a rock unlike the white granular quartzite of Carn Rock, and the latter band would seem to strike north of the quarry. But 100 yards south of the quarry there is another small pit, in quartzite like that of Carn Rock. Perhaps also the fossiliferous grey quartzite blocks seen on the shore, to which is cemented the thin band full of trilobite remains, represents still another horizon; but all these bands seem to occur crowded within a small thickness of strata. Unfortunately this complicated area is much obscured by landslips and vegetation.

North-west of Trewollock a pit in the field near the high road shows quartzite again, nearly surrounded by sandy slates, apparently Devonian. The boundary is a very puzzling one, and as no conglomerate can be found, the junction is probably a low hade overthrust.

The sections seen in the road from Gorran Haven to Church Town show that a large lenticle of quartzite must be crossed close to the junction of the two roads to the coast. Numerous large blocks are scattered about, or have been built into the hedges, and many others have lately been removed for road-metal. Other small exposures of quartzite occur a quarter of a mile further north, and in the road just below the smithy. This latter exposure, which is in the lane leading down to Church Town, is probably close to an overthrust junction of quartzite over Devonian strata, this overthrust boundary being a continuation of the thrust-planes of Catasuent and Porthluney, though south of Treveor there is a trace of the basement conglomerate. The plateau is all agricultural land and the few inland exposures are so isolated as to defy interpretation, the junctions will again be referred to when we trace the Devonian boundary.

Between Caerhays and Portholland the Lower Palæozoic rocks are hidden by later deposits; but the ridge west of Portholland is occupied by crush-breccia or mylonite containing large masses of quartzite. There are no good sections; but probably for a mile or more both the boundaries are thrust-planes, no true conglomerate being found till Trethenell is reached. This ridge seems to contain a number of lenticles of quartzite, represented by scattered groups of large blocks. No igneous rocks were observed.

The igneous rock of Sunny Corner, Portloe, will be described later on, all that need here be said is that it seems to form a sheet with crushed slate above and below, and its junction with the Devonian strata is probably a thrust-plane. Quartzite masses, like that of the Cuckoo Rock, occur at Camels, and seem to lead on to the largest exposure of quartzite in the district, that forming the Carne ridge. The strike of the Carne quartzite is very curious, for it suddenly curves from south-west to due south. The rock is excellently seen in the large road-metal quarry immediately south of Carne. Photographs of this quarry, and also of the conspicuous ridge leading to the coast were taken by Mr. Hall, and have been deposited in the Survey collection. This quartzite yielded to Mr. C. W. Peach specimens of *Orthis calligramma* (now in the Penzance Museum), but we have not been able to add any other species and close search has not led to the discovery of anything like the trilobite-band of Perhaver Beach, or the band with the fine-ribbed *Orthis* seen in Perhaver Quarry. Quite recently, however, a good trilobite has been found in the Carne Quarry (see p. 29).

The singular bend in the strike just alluded to affects also the other boundaries near Carne. It probably results from the piling up and packing of the great mass of greenstone of Nare Head, which is so enormous as to cause an exceptional diversion of the regular strike. It is difficult to understand; but I can only explain the structure as resulting from the same dragging action which has torn up and transported large masses of serpentine, gabbro, and Silurian limestone from a region lying some distance to the south-east of the Head. This dragging

action along a thrust-plane is apparently an exceptional feature almost unrecognised elsewhere; but the whole structure of the Gorran area shows that it must have taken place. Perhaps the explanation of the difference may be that the principal areas of overthrusting previously studied had once been buried under an enormous mass of superincumbent strata, since denuded, and the thrust-planes have very low angles. In the Gorran district, on the other hand, there has been less denudation and we still see the upward curve of the thrust, where it took the path of least resistance and was tending to break out at the surface. The average inclination from the horizontal of these planes near Gorran is probably about 50° . This superficial region, where the thrust broke out, would probably be greatly shattered and contorted, instead of exhibiting a single clean-cut plane of movement, like the path taken by a deeply buried thrust.

Before leaving this question it may be well to draw attention to the similar phenomena exhibited by the Ridgeway fault, between Dorchester and Weymouth. In this fault we see a thrust-plane of Tertiary date curving upwards and breaking out at the surface, and causing disturbance both above and below in much the same way as do the more ancient movements.¹ If we take still more recent movements and study the structures exhibited in the cliffs of Contorted Drift near Cromer, we find even more striking resemblances—we find lenticles and eyes of all sorts of rocks, around and past which the matrix has flowed, we find shearing, as at Gorran, carried to such an extent as to produce a new parallel structure, so resembling true bedding that it is often taken for bedding.² Indeed the resemblance is so close that if we compare the photograph reproduced in Plate 7 of this Memoir with some of the photographs of Contorted Drift in the Museum of Practical Geology, it is difficult to realise that the one is Palæozoic the other is Pleistocene. At Cromer the moving mass represents the rock over the thrust-plane, the thrust-plane probably occurring at the junction of the frozen mass with the unfrozen strata below. Where the plane meets rising land it has to bend upward and everything is sheared into lenticles as at Gorran; but the beds below the main thrust are scarcely disturbed. Can it be that the unsheared masses of soft Silurian limestone have been torn up from below the plane and carried some distance, in the same way that the masses of soft chalk have been transported and deposited between Pliocene and Pleistocene strata near Cromer? The resemblances between the ancient and modern disturbances of Cornwall and Norfolk are so close that it is difficult to avoid comparing the ice-sheet with its basal mass of frozen strata to the moving mass over the thrust-planes at Gorran. In each case the great disturbance and contortion is purely local; occurring only where the horizontal thrust gives place to an upward movement.

¹ Reid, 'Selection of a Fault and Locality suitable for Observations on Earth-movements.' *Rep. Brit. Assoc. for 1900*, p. 108.

² See Reid, 'The Glacial Deposits of Cromer.' *Geol. Mag.*, 1880, p. 55; also 'Geology of the Country around Cromer.' *Mem. Geol. Survey*, 1882.

After leaving the quartzite area we enter a belt of highly calcareous slate, in which movement has not been so extreme. These rocks, which appear in the cliff between Gidleywell and Pendower, have already been described; they extend continuously through the village of Vryan to Polgrain and Trevennen, and there are a few inland sections which should be referred to. The slates are soft and commonly weather a pale colour, or show stains of manganese; at the surface most of the calcareous matter has usually disappeared and the limestones are only to be seen in the deeper road-cuttings. The radiolarian cherts remain unaltered and are traced without difficulty across the ploughed fields. As these strata do not appear in Perhaver Beach we must follow them in the reverse direction, beginning at Vryan.

In the village of Vryan (15 on Index Map) this division is well exposed in the numerous deep road-cuttings, and the cherts have been discovered in several places by Mr. Howard Fox (*op. cit.*); perhaps the best section of these cherts is one seen in the foot-path a quarter of a mile north-west of the church (16 on Index Map). They occur also, associated with very micaceous slate and coarse micaceous grit, in the curious spur east of Treburthes, the section laid bare in the path which crosses this spur seeming to show a continuous sequence and transition into grits of the Portscatho type.

Slight trace of the cherty slate have been found at Trengrowse, near Tippet's Shop, and near Trevilveth; but on the level plateau sections are scarce. The steeper slopes towards Polgrain show better exposures, a large amount of chert, often with traces of radiolaria, occurring in a field just above the high road between the two branches of the stream north of Polmenna (17 on Index Map). The chert here is finely laminated and contorted; but there is no sign of cracking or quartz-veining at the sharp folds; the crumpling seems to have been completed before the calcareous slate had become a chert. This late silicification may be the reason why so few pieces show any trace even of the siliceous radiolaria, and why other fossils are not to be found; the calcareous fossils were probably destroyed before the silicification took place.

Several sections of the slate, limestone, and thin radiolarian cherts will be found close to Polgrain (18 on Index Map), and another small exposure of chert was noticed by Mr. Fox close to the igneous mass seen in the road-cutting west of Tubbs Mill. The chert was not found in the inlier of Lower Palæozoic rocks between Trevennen and Trevarrick, and as the slates are dark-coloured and sparingly calcareous they may belong to the higher non-calcareous division; there is perhaps a trace of much sheared quartzite in the road-cutting at Trevarrick.

The next division, the Portscatho Grit, calls for little remark, it consists of grey sandy slate with numerous thin bands of hard moderately coarse grit. It is best studied just outside our area, in the cliffs and foreshore of Gerrans Bay, but quarries will be found a quarter of a mile south of Treburthes and also west of Penhesken. In the road-cutting below Cregoe it takes the less

usual form of micaceous sandy slate. Around Tregoney numerous quarries and road-cuttings will be found, but the rock is mainly a hard sandy slate or even a grey platy slate. This type is well seen in some quarries on either side of the Fal close to Tregoney and in the long road-cutting between Tregoney Bridge and Reskivers. There would seem to be a gradual transition into more argillaceous and silty rocks of the Falmouth type in the area north-west of Tregoney, close to where the Falmouth Slates come to the surface in the adjoining Map.

As regards the geological age of the rocks described in the last two chapters, it was seen that the most satisfactory evidence was likely to be yielded by the trilobites from the fine-grained quartzite of Perhaver Beach, for other fossils, except two or three species of *Orthis*, are rare. Mrs. Reid collected a number of specimens from this thin band, and Mr. Philip Lake has been so good as to determine them. They belong to:—

Cheirurus Sedgwicki <i>Salt.</i>	Phacops mimus <i>Salt.</i>
Calymene Tristani <i>Brongn.</i>	„ incertus? <i>Desl.</i>
„ cambrensis <i>Salt</i>	Asaphus Powisi? <i>Murch.</i>

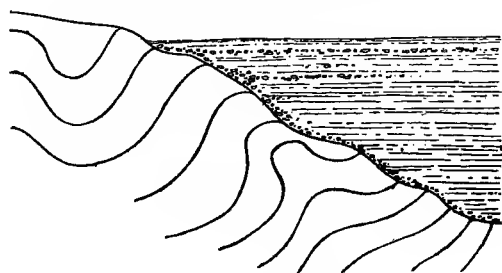
Mr. Lake adds that “the beds are apparently Llandeilo; but a good deal depends on the definition of ‘Llandeilo.’ They evidently correspond either with the Angus slates or the *Grès de May* of Brittany and Normandy.”

CHAPTER IV.

DEVONIAN ROCKS.

The Upper Palæozoic rocks included within our area are all of Lower Devonian age. They are of exceptional character, for they represent the fringing deposits of a Devonian sea, and overlap in such a manner that the strata in contact with the Ordovician rocks are not necessarily, or even probably, the oldest of those that appear at the surface, even in this limited area (Fig. 4). Beach deposits of well-worn shingle appear in various places in contact with the older rocks; but finer-grained conglomerates also occur at Pentewan, several miles from the old shore-line and in contact with the Meadfoot slates. This

FIG. 4.—DIAGRAM SECTION SHOWING THE RELATION OF THE DEVONIAN TO THE OLDER ROCKS.



appears to indicate that while the Pentewan conglomerate was being deposited the sea a few miles away was still cutting into the Lower Palæozoic land. It seems quite possible therefore that the beach conglomerate of Porthluney and Portloe may be of the same date as the conglomerate seen at Pentewan.

Unfortunately the discovery of this unconformable overlap destroys all hope of working out the relation of the Devonian rocks to the Older Palæozoic series in Cornwall. In other parts the junction is either deeply buried or faulted; here it is unconformable. Only a few miles away, near Newquay, we find rocks of the Lower Old Red or Dartmouth type well represented, though here they have been completely overlapped. A study of the two areas suggests also that the Meadfoot Series is also overlapped as we approach the old shore-line, the sandy and conglomeratic strata around Gorran and Grampound representing only the upper part of the Lower Devonian—the Staddon Grit of districts further north.

The exact relations of the sandy and conglomeratic strata in the Pentewan country to the Meadfoot Series cannot, however, be worked out in the area we are describing, as the cliff-section is

much confused and the rocks are greatly contorted. Mr. Ussher thinks that the Grampound Grit may pass below the Meadfoot Series, or represent that series. This question was discussed in 1905.¹

MEADFOOT BEDS.

North of Pentewan lies a small area of black somewhat calcareous slate, in which occur badly preserved fossils, principally ossicles and stems of crinoids, with a few simple corals. These strata, which within our area have yielded no well-preserved fossils, are continuous with the Meadfoot Series. They are well seen in the cliff north of the Harbour, where they seem to pass by alternation into the grit and conglomerate. But, as already mentioned, the strata are too much folded and contorted for it to be possible to say from such a section which way up they should lie.

GRAMPOUND GRIT.

These strata, which unfortunately in the area under consideration are unfossiliferous, and outside it have only as yet yielded one fossil, consist in the main of grey sandy slate, alternating with thin bands of grey grit. With these occur masses of conglomerate, containing pebbles derived from the Ordovician quartzites and igneous rocks. The distribution of the conglomerate is peculiar; it forms, as we should expect, a continuous stratum wherever we find an unfaulted junction between the grit and the older strata; but it occurs also in narrow bands, striking east and west between Pentewan and Creed.

Before further discussing the relation of these conglomerate bands to the main mass of conglomerate in contact with the Lower Palæozoic rocks we will describe the coast and inland exposures; but as the Grampound Grit is very uniform it will be of no use to give descriptions of any but good exposures, or of quarries in which something unusual is seen. As regards the inland boundary with the Meadfoot Series, the only thing that need be said is that it is apparently as obscure and as contorted as the junction seen in the cliff, with the added uncertainty that we have to depend on the evidence seen in ploughed fields. No doubt the two divisions are contorted together; but if they also alternate towards the junction the boundary must really be a very complicated one. The flowing broken line engraved on the map represents an average of several alternative boundaries; and is even more uncertain than the other broken lines.

It will be most convenient to commence, as before, by describing the cliff-section, which is an excellent one though its interpretation is not easy. The cliff at Pentewan shows grey slate in contact with sandstone and coarse grit. The band of grit will be found in the point just opposite the Harbour mouth, where it contains small pebbles of slate and quartz, seldom exceeding a

¹ 'Summary of Progress of the Geol. Survey for 1905,' pp. 25-29.

quarter of an inch. The strata are much quartz-veined and contain also a few veins of calcite.

South of the Harbour the cliff is dark slate alternating with thin bands of grit, the whole being much contorted and veined. A band of coarse felspathic grit with small slate fragments, seen at Portgiskey, is very like the band at Pentewan.

The small point south of Portgiskey shows also a band of peculiarly glossy black slate, in which occur the thin seams of cherty carbonate of iron and manganese, described by Mr. Howard Fox and Dr. Teall.¹ These curious cherty seams turn out to be of considerable importance, for they have now been traced here and there from sea to sea, from near Mevagissey to Perranporth, and appear on a definite horizon. Perhaps the manganese may be derived from the Vryan slates, which contain an exceptional quantity of this substance.

Between Portgiskey and Penare Point the cliffs rise to 260 feet and are formed of alternating dark slate and grit. The dips are exceedingly high and irregular, generally northerly, but in one place close to the Point the folds dip south. The strike is about west-south-west. These high dips would seem to indicate merely the pitch of the folds, and in such cases the higher the apparent dip the more likely the true dip is to be horizontal. That such is the case here seems to be borne out by the reappearance of the peculiar bands of cherty carbonate at Polstreath, where black slates contain a few thin bands of grit and of these carbonates, the latter associated with exceptionally glossy slate. Manganese has also been found in black slate in a well close to Mevagissey.

The cliffs south of Mevagissey show dark slate and grit; but one of the most convenient sections to examine will be found in the quarry at the cliff edge just south of Stuckumb Point. The alternation of dark glossy slate and thin bands of coarse grey grit makes the beds strikingly like some parts of the Portscatho Series.

Polkirt Beach shows slate cleaved through sharp contortions and much disturbed since. This is one of the places where the later disturbance is most extensive and most clearly distinguishable from the earlier one. We cannot fix the date of the movement, but there is no new cleavage associated with it. The rocks in this part of the cliff are very like those of Chapel Point; and the cherty carbonates have disappeared.

Immediately south of Portmellon there are alternations of glossy slate and sandstone, with a band of coarse grit, the last containing large flakes of mica and chips of slate. Dips within two hundred yards of each other give 80° south-south-east and 80° north-north-west. About a quarter of a mile south-east of Portmellon we find confused strata of sandy slate and sandstone, nearly vertical but dipping either way. These rocks would seem to be somewhat calcareous, for a little tufa is deposited on the

¹ 'The Radiolarian Cherts of Cornwall.' *Trans. R. Geol. Soc. Cornwall*, vol. xii., 1906, pp. 15, 16.

cliff face, though no markedly calcareous band could be found. Some very obscure markings in the slate in this neighbourhood suggest badly preserved algæ; but they were too obscure to be worth preserving, and no other indication of fossils could be found.

Close to Roward's Quay (just north of Chapel Point) grey sandy slate and grit are contorted and cleaved and the cleavage has afterwards been bent. The rocks become more sandy around Chapel Point, and consist mainly of grey sandy slate and grit. At Pabyer Point more massive grits occur and these become coarser close to the fault which ends the Devonian cliff in Great Perhaver Beach; but no true conglomerates are there found, though there are a few pebbles up to a quarter of an inch. We seem to be approaching the base of the Devonian system, but the actual basement beds have here been faulted out.

About a quarter of a mile south of this fault we find, however, on the shore near low-water mark, some large blocks of the characteristic basal-conglomerate. These occur within a few yards of the disturbed belt described in Chapter II (pp. 13-16) and have perhaps been picked up by the overthrust and transported in the same way as the masses of Silurian limestone seen in the immediate neighbourhood. The blocks of conglomerate, however, were always surrounded by beach sand whilst the Survey was in progress, and their relations to the other strata could not be made out.

If we follow the Devonian boundary westward from Great Perhaver, we find that the line is a very complicated one, the strata being sharply folded, overthrust, or cut off by normal faults. The first part of the line is obviously a fault, of fairly late date. Then comes a very puzzling piece of boundary, which seems to coincide with an overthrust fault, for no trace of the basal conglomerate can be found till we reach Treveor, south of which place it has been ploughed up. Then follows another obscure piece, till we reach the band of conglomerate which leads to the cliff on the east side of Porthluney.

The junction of the conglomerate with the adjoining rocks is sheared through and overthrust, as is usually the case in this district where rocks differing in rigidity come together; but the displacement seems to be of no importance. The section, however, at first sight appears to be so confused that it may be convenient to explain what the mapping shows to be the relation of the Upper to the Lower Palæozoic rocks at this point.

Porthluney Cove coincides with a sharp syncline, the sides of which have been crushed together until they are almost parallel, one side being overturned. The rocks forming the floor of the Cove consist of fairly soft black slate full of small pale lenticles, obviously Devonian slate. On either side of the Cove the cliff shows a band of conglomerate dipping south-east. The band on the west side is only thin and is so sheared out that Devonian and Ordovician slates almost touch. On the east the conglomerate has expanded into a thick mass, which can be seen to overlies the Devonian slate and to pass under the Ordovician igneous rocks,

though it is clearly composed to a large extent of pebbles of that rock and of the adjoining quartzite.

The conglomerate is a thick mass of pebbles, cemented together by silica in such a way that the rock breaks as readily through the pebbles as through the matrix. It is greenish grey, weathering buff or reddish, and where it weathers the pebbles occasionally stand out, though as a rule they are so much strained and flawed that they fall to pieces as they weather out; this makes it somewhat difficult to make a satisfactory study of the different rocks represented. A few of the pebbles exceed three inches across, most are under two inches.

The pebbles are well rounded, and a comparison between the siliceous pebbles in the conglomerate with the fragments of similar rock in the crush-breccias is the best means of distinguishing between the two types. A few yards east of the Porthluney conglomerate crush-breccia greatly resembling it will be found, and to add to the difficulty it seems to contain an occasional torn off lenticle of true conglomerate; but the fragments of vein quartz and quartzite are angular or lenticular, though the softer rocks are more rounded. In the true conglomerate we find no trace of Upper Silurian or Lizard rocks, the bulk of the mass being made up of quartzite of different types, vein-quartz, and decayed igneous rock. Dr. Teall, who examined the pebbles, records also subophitic dolerite, andesitic basalt, and keratophyre of the types occurring in the felsitic ash group. There are also some small pebbles which suggest radiolarian chert, though no trace of radiolaria was seen.

On the west side of Porthluney Cove a thin streak of conglomerate will be seen in contact with Ordovician slate. The latter only continues for a few yards round the point, giving place again to grey sandstone and slate, over which it appears to be thrust. This sandstone stretches as far as the next belt of greenstone, in the middle of which occurs a narrow dyke-like mass (too small to be shown on the one-inch map, though it appears on the section). On either side of this band is a narrow seam of basal conglomerate, showing that we are dealing with a very sharp infold, not with a fault. The western boundary of the greenstone shows no conglomerate; though the inland continuation of this border in the wood opposite Caerhays Castle has it well developed. The road-cutting south of Caerhays Castle shows also a good section of conglomerate east of the greenstone.

The cliffs near Portholland consist of massive grit and sandy slate, which become more and more shattered as we approach Portloe. Directly we again approach the base, conglomerate however reappears, and is well shown between Caragloose and Hartriza Points. The composition here is peculiar, for the pebbles consist mainly of large and small fragments of sheared and puckered gritty phyllites, approaching in character to mica-schists. These pebbles have some resemblance to rocks of the Dodman series, though they cannot be definitely indentified as having been derived from that series.

Conglomerate is again found on either side of Portloe Cove, but the finest exposure of all will be found on the south-west side of Jacka Point, accessible by a rough track at the Zawn. Here is visible in the cliff a thick mass of conglomerate, passing under greenstone, and the fallen blocks smoothed by the sea give excellent opportunities of examining it. The conglomerate is exceptionally coarse, with pebbles sometimes as big as a man's head. Again the constituents have altered, for amongst the larger and most abundant are boulders of an altered granitic rock, essentially composed of quartz, orthoclase, and oligoclase, and also of a sheared felspathic sandstone containing flakes of muscovite. Some of the smaller pebbles belong to igneous rocks of unknown origin.

The continuation of these cliffs is largely a mass of crush-breccia in which we find our way with difficulty; but again near Manare Point true conglomerate is discovered in contact with the greenstone. At Parc Caragloose and in Kiberick Cove the basement beds appear to be overlapped by the overthrust greenstone, though in the western corner of Kiberick Cove detached blocks of conglomerate appear on the foreshore, as they do on Great Perhaver Beach. On the west side of Nare Head the basal conglomerate reappears on the foreshore beneath the eastern horn of Mallet's Cove, and again on the east side of Paradoe Cove, where it seems to form a large sheared lenticle, not traceable for any great distance, even in the cliff.

When we attempt to follow the conglomerate inland it soon becomes evident that the conditions around Portloe and Veryan must be very similar to those exhibited in the cliffs. At one spot there is a normal junction with the Lower Palæozoic rocks, at another place along the same line the junction is an overthrust which appears to have cut out the conglomerate. This difficulty, and the large amount of grass land, makes many of the boundaries very uncertain, it will therefore be useful briefly to indicate the inland localities where conglomerate undoubtedly occurs.

The junction between Upper and Lower Palæozoic rocks between Nare Head and Portholland seems to be a thrust, but the shattering has gone so far that away from clear sections it is difficult to say exactly what happens—the rock ploughed up is crush-breccia, not conglomerate. Where the line turns back towards Veryan there is also no clear evidence; but north-west of Trethenell the true conglomerate reappears for about half a mile. A quarry in the field west of Veryan Vicarage is in massive coarse sandstone, which must be close to the base, and the junction is probably normal. True conglomerate is again found when Crohans is reached, and it can be traced for half a mile.

It appears, therefore, that in the neighbourhood of Trethenell and Crohans the long strip of Devonian rocks lies in a true syncline, for a conglomerate base occurs on either side.

As we recede from the belt of extreme movement the strata become less shattered and the bedding more recognisable. A

good section of little-altered micaceous sandstone and sandy slate can be seen in a quarry half a mile east of Tippet's Shop, close to the field road to Penvose. The base of the Devonian rocks in this neighbourhood seems to consist of a coarse grit or fine-grained conglomerate, first noticed by Mr. Upfield Green, which is well exposed in the worn surface of the road to Lower Polmenna. Unfortunately the junctions around Polgrain, Tubbs Mill, and Trevarrick are everywhere obscured.

The boundary of the Devonian strata now turns off in a north-westerly direction, but as already observed it is probably more complicated than has been drawn over the parts of the plateau where sections are so scarce. Conglomerate is again found, and has been quarried for walls, close to Tregonan and at Carveth, so that there is little uncertainty as to the exact boundary.

The neighbourhood of Creed shows a peculiarity in the lithological character of these rocks which may go far to explain the general structure of the country. Instead of conglomerate being confined to a thin sheet at the base of a mass of sandstone and shale, it appears again and again, away from Lower Palæozoic rocks, for a distance of two miles to the north. The associated beds also are taking on more the character of a coarse grit as we approach Grampound, which lies just outside the map up the valley of the Fal. It will be worth while to devote a little space to a description of this north-west corner of our area.

If we study the Devonian rocks in strips parallel to their strike, we find first, at the base round Carveth, conglomerate of the normal type, and this band seems to have spread to a quarter of a mile broad. It is followed by coarse grit of the Grampound type, which will be seen in three quarries north of Carveth. This grit is very like that of Mevagissey; and west of the Fal, at the Roman Camp, the sections show also alternations of thin slates and grits, associated with glossy slate containing thin seams of cherty carbonate.

Around Creed conglomerate reappears, an excellent section of coarse blue grit with large fragments of slate being exposed on the south, in the quarry a few yards west of the high-road, in the bank of a small tributary of the Fal. The road-cutting nearer Creed shows alternating sandstone and fine conglomerate, and similar strata occur in the west bank of the Fal opposite Creed. Conglomerate, with pebbles up to two inches across, even reappears as much as a mile and a half north-east of Creed, outside our area.

The strike here has become nearly east and west, and if the strata are followed in an easterly direction from Creed, conglomerate or very coarse grit appears again and again, and will be seen at Gargas, Ventonwyn, and in thin bands in a quarry close to the high-road south of Tregian. From this point conglomerate and grit are found here and there to Pentewan.

We thus find that the two widely separated bands of conglomerate found at Pentewan and Porthluney converge and practically meet at Creed, the intermediate area, probably synclinal, being occupied by slate and grit of the Grampound

and Mevagissey type. The interpretation of this phenomenon is not free from difficulty; but the most probable explanation seems to be that we see here a structure such as is shown in the diagram in Fig. 4 (p. 40); but that the bedding has also been thrown into folds. The conglomerate forms a continuous sheet at the base, where Devonian rocks abut against the ancient land; but away from the shore line conglomerate only extends for a short distance. It may, however, be found in tongues in any part of the deposits laid down whilst a rocky shore a few miles away was still being attacked by the sea. In the absence of characteristic fossils from any of these sandy and conglomeratic deposits, we cannot say whether the Pentewan conglomerate is the exact equivalent of any part of the basal conglomerate now seen. The basal conglomerate itself is probably of varying age in different places, and if we could trace it further north we should probably find it passing imperceptibly into beach deposits of far older date.

A few other inland exposures of the Devonian strata deserve special mention, and first it will be advisable to allude to the Grampound sections, for though this place lies just outside the area, a mile north of Creed, it gives its name to the division. On the west bank of the Fal, immediately north of the high-road at Grampound, will be found a large road-metal quarry in coarse massive grey grit. This is the typical 'Grampound Grit,' which closely resembles the massive grit seen at the north end of Perhaver Beach. On the east bank of the Fal, nearly opposite, is another large quarry, in purplish-grey flaggy slate and black slate with carbonaceous matter, quarried for building. These two quarries well illustrate the two common Grampound types.

Massive grit, apparently on the same horizon as that of Grampound, occurs at Luney, which is just on the north border of the Map. Near Tregian Cottages, in St. Ewe parish, an instructive series of quarries is found, for the rocks are so like those of Grampound that it is difficult to resist the conclusion that they are on the same horizon, though the variable strikes noted are all south of west, instead of due west or north of west. The quarries further towards the west at Tregian are in grey micaceous sandstone, grit, and sandy slate, with a thin band of conglomerate; a quarry south of the stream shows massive coarse sandstone. Another large quarry, at the fork of the roads close to Trelean Vean, is in hard flaggy slate, formerly worked for roofing, but of poor quality. This group of strata in closely associated pits is scarcely distinguishable from that mentioned as occurring in Grampound. Another pair of quarries, the one in massive grit, the other in dark platy slate, will be found in the wood on the north side of the high road at Peruppa.

Large quarries in the grit will be found at Polnassick (behind the Bible Christian Chapel) and in the valley east of Trevascus, where it contains fragments of slate of noticeable size. There are numerous other quarries and road-cuttings through these beds, but the sections so resemble those seen in the cliff along the same line of strike that there is no need to describe them.

No trace of igneous rock has yet been discovered anywhere in this series, and it is also very difficult to find any band sufficiently calcareous to show the slightest effervescence with dilute acid. The entire absence of fossils therefore may be due to two different processes, the rock may have been decalcified before shearing, or even before they were hardened, and the slates may afterwards have been so sheared as to obliterate all trace of impressions of fossils. The only chance of finding recognisable fossils in this disturbed area in the sandy beds seem to be in the massive grits which have resisted shearing. One of the grit quarries near Grampound has lately yielded a single impression of *Orthis* (apparently a new species) and others may be found. Until we obtain some determinable species it will be impossible to say definitely to what zone in the Lower Devonian sequence any particular part of this variable littoral sequence may belong.

CHAPTER V.

IGNEOUS ROCKS.

The igneous rocks of the district fall naturally into five groups. In the first place there is the granitic gneiss of the Eddystone, perhaps of Archæan date. Secondly, we find masses of gabbro and serpentine, like those of the Lizard, but only occurring as enormous lenticles in a belt of crush-breccia along a plane of movement. Thirdly, in the Ordovician rocks occurs a group of basalts, allied to the 'pillow-lavas' of Mullion Island, associated with soda-felsites and perhaps ashes of similar composition. Some of these rocks are intrusive, others are undoubtedly contemporaneous with the sediments among which they occur; but all seem definitely to be of Lower Palæozoic age, as they are cut off above by the Devonian basal conglomerate. The fourth group contains only the diabase of Black Head, which was perhaps intruded as a sill into the Devonian slates before they were folded; it may be either of Devonian or Carboniferous date. Lastly, we find a single dyke of quartz-porphyry, representing the well-known group of Cornish elvans. This dyke cuts across both contortion and cleavage, is later than the granite intrusion, and is probably either late Carboniferous or Permian. The granite itself does not enter the area; though it occurs three miles to the north, in the St. Austell mass. In the following notes these different groups are dealt with in order of date, their stratigraphical relations being explained as far as the confused geology will permit. To this Dr. Teall has added petrological descriptions, where the state of preservation of the rock allows; but unfortunately in a good many of the sections the igneous rock, though recognisable as such, is so much sheared and so much decayed that nothing more can be said about it.

As regards this question of the bad state of preservation of so many of the rocks, it may be remarked that a study of the derivative pebbles found in the Devonian basal-conglomerate shows that many of the pebbles had been strained, and I think also much weathered, before this conglomerate was laid down. The Carboniferous cleavage and shearing, acting on rocks already strained and altered by percolating water in Lower Palæozoic times, and probably affected also in some cases by weathering during the Devonian Period, has naturally resulted in the breaking down of both rocks and minerals, especially at places where the igneous rock and the conglomerate come in contact. The specimens taken for microscopic examination were carefully selected from interior of the best of the solid 'eyes' or lenticles which have escaped shearing; but in certain of the rocks, such as the doubtful volcanic ashes, no such specimen could be found,

though exposures were abundant and close search was made. Some of our conclusions, both stratigraphical and petrological, have therefore been come to with the greatest hesitation.

GNEISS OF THE EDDYSTONE.

The Eddystone Rocks consist of a small group of low wave-swept and submerged reefs, lying nearly twenty miles about east-south-east of the mainland at Gorran Haven and surrounded by sea. They occupy a distinct sheet of the Ordnance map (354), but for convenience this small area has been transferred to 353, in the form of an inset map. It has been attached to this map and described in this Memoir, because these isolated rocks seem to form the last relic of a mass of very ancient land. It is probably part of a rigid Archæan complex running about east-north-east and west-south-west, and governing the trend of the folds and earth movements with which the present pages are so largely concerned.

The rock of the Eddystone was thus described by De la Beche: "The rock . . . being a variety of gneiss similar to some occurring near Prawle Point, a kind of connecting link is obtained between one district and the other (*i.e.*, between Start and the Lizard), which would give a west-south-west and east-north-east direction for the general bearing of the rocks of the Bolt Head and the Lizard, supposing them to be of the same geological age."¹ After the lapse of nearly seventy years this question remains much as De la Beche left it.

Thanks to the courtesy of the Corporation of Trinity House and of their engineer, Mr. Thomas Matthews; we obtained a large specimen of the rock, which is described petrologically by Mr. H. H. Thomas as a—

Garnetiferous granitoid gneiss, pale pink garnets, yellow-brown to brown-green biotite intergrown with muscovite and containing needles of apatite. Large plates of plagioclase felspar (low extinctions) decomposing and giving rise to prisms of epidote and flakes of muscovite; the crystals are strained and the twin lamellæ curved. Patches of quartz-mosaic, the individual grains showing strain shadows. Epidote occurs in larger prisms outside the felspars (Slide E. 4393). Another specimen (E. 4392) shows an 'eye' of large plagioclase crystals and a mosaic of quartz, surrounded by large masses of biotite, muscovite, epidote and garnet.

This description is given in full, as the rock is inaccessible, but fragments of it might be expected to occur in the Gorran district, either associated with the other transported masses in the crush-breccias, or as pebbles in the true conglomerate. Thus far nothing answering to this description has been found, though the Devonian conglomerates yield pebbles which seem to belong to other schistose rocks, belonging probably to submerged parts of the same complex.

¹ 'Report,' p. 32.

GABBRO AND SERPENTINE.

In Chapter II. the mode of occurrence of these rocks has already been described; they occur in this area only as detached masses torn up and carried along by an overthrust fault. Before 1839 the small exposures of serpentine and diallage rock in Kiberick Cove had been discovered by De la Beche, who noticed their extremely local distribution, pointed out correctly how close is their resemblance to rocks of the Lizard peninsula, but accounted for them as a local outburst.¹ A few years later the Rev. J. Rogers gave one or two additional details²; but otherwise the question of the relations of these rocks to the surrounding country remained as De la Beche left it until the new survey was made.

Both rocks are highly altered and often much impregnated with carbonates, but their original characters are sufficiently well preserved to leave no doubt that, in their original condition, they were identical with certain types occurring at the Lizard, as was pointed out by De la Beche and Professor Bonney.

The only other occurrence of allied rocks within our area is found in the numerous pebbles of gabbro with linear foliation, already referred to as occurring on the beach in Gerrans Bay. The curious rod-like structure is very conspicuous in these pebbles, and the rock forms the third characteristic Lizard type already recognised in this district.

BASALT AND DOLERITE.

The Ordovician greenstones, though closely associated, are of two distinct types, the one containing basalt and dolerite, the other including only a soda-felsite and some allied felspathic rocks, perhaps ashes, of very limited distribution. We will deal first with the basalts and dolerites.

The mode of occurrence of these rocks is so well shown on the map and section that there is little to add. In every case the isolated mass seems to be a sheared, much broken, lenticle; the larger masses seem to be made up of lenticles thrust one over another, packed, and piled up, often with much incidental brecciation, and shearing. This characteristic lenticular appearance is well exhibited in Plate I. The shearing has gone on to such an extent that wherever a section is visible the outer surface of the igneous mass is seen to have been torn away, and either becomes a brecciated outer layer, or is drawn out into thin streaks and films which alternate with the slate. Careful search was made for contact alteration, for it is still a moot point whether the so-called 'pillow-lavas' are true outflows, or are intruded sills; but no satisfactory contact alteration could be found, except in one case, where later veins clearly penetrate an earlier igneous mass.

¹ 'Report on the Geology of Cornwall,' etc., pp. 84, 85.

² 'Notice of the Serpentine of Pennare.' *Trans. R. Geol. Soc. Cornwall*, vol. vi., 1846, p. 41.

The distribution of the greenstones suggests that they are perhaps confined to one horizon, a circumstance somewhat in favour of their volcanic origin; but the geology is too confused to allow us to speak with any confidence, especially when we cannot prove from internal evidence whether the rocks are lavas, dykes, or sills, or whether any of them are bedded tuffs. Igneous rocks occur abundantly in association with the quartzite, and also in an isolated mass around Tubbs Mill, which however may be a repetition of the Perhaver greenstone; they seem to be absent from the Dodman phyllites, the Portscatho grits, and probably from the Veryan calcareous slates. The puzzling Tubbs Mill mass may perhaps occur in the last-named series, though no igneous rocks occur in it around Veryan; in Mullion Island pillow-lavas are intimately associated with thick radiolarian chert, and traces of chert have been found close to the greenstone of Tubbs Mill.

In view of the want of continuity of the masses the most convenient way to describe them will be to take them in order from east to west. The most easterly exposure is that shown in the Gwineas or Gwinges, a small islet about a mile from Gorran Haven, and over half a mile from Pabyer Point. This islet consists of a badly-sheared greenish igneous rock, vesicular in places and largely composed of epidote; but the microscope throws no further light on it. It is very calcareous, and this may have given rise to De la Beche's statement that the isle is a continuation of the calcareous rocks of Gorran Haven. I could find no sedimentary strata, and the mass looks a good deal like the Great Perhaver basalt; it is not clear on which side of the Perhaver fault it occurs, for it is nearly in a line with that fault.

The igneous mass which forms Great Perhaver Point has already been referred to. It seems to die out within half a mile; it is composed of a packed mass of lenticles of varying size. This lenticular shearing and packing has proceeded so far that any 'pillow-structure' that may have existed has been masked, though on its north side the rock is often highly vesicular. The junction with the slate on that side, however, is sheared away, whilst on the south side it is faulted and brecciated. It should be remembered that in an area so disturbed as this, two rocks of different hardness coming together will almost inevitably have their junction sheared. These constantly occurring strike-faults are not necessarily of much importance, though it is almost impossible to distinguish between them and thrusts of great magnitude. Slight indications in this case suggest that the sequence on the north side of the sheet is nearly continuous, whilst on the Haven side the junction may be a fault of considerable importance.

The igneous rock which appears on the west side of Percunning Cove is much sheared up with slate. It may be a continuation of the Great Perhaver mass, with which it closely agrees in stratigraphical position. It can be followed for about half a mile inland, striking towards Perhaver.

The igneous rock on which the conglomerate of Porthluney rests, to the naked eye somewhat resembles the decayed part of

the mass at Perhaver. With some difficulty a fairly sound specimen was obtained, and this turns out to be a massive epidiorite. The rest of the greenstones seen on the coast between this point and Nare Head seem to be parts of one sheet of pillow-lava, which will be again alluded to. The curious brecciated rock of Sunny Corner, Portloe, will also be referred to again; its relations to the surrounding strata are very obscure.

The Tubbs Mill rock, though so closely resembling the other pillow-lavas, seems to be on a different horizon, for it is intimately associated with pale slate and radiolarian chert, like that of Vryan. The mass is apparently a large lenticle overlapped unconformably by the Devonian rocks. It is much interbanded with slate on the south-east, but in the heart of the mass there is one excellent section, that above Tubbs Mill.¹ The field evidence shows that the whole mass is formed of highly porphyritic rock, curiously intermingled with fine-grained greenstone, just as is the case in the quarry.

The large road-metal quarry of Tubbs Mill lies on the east side of the stream, and just north of the high-road which leads to Mevagissey. It shows excellent sections, constantly varying as the quarry is cut back, and the rock is so massive that it has resisted shearing to an extent unknown elsewhere in this district. Not only has its massiveness helped to preserve the rock, but the locality also is at an exceptional distance from the belt of most extreme movement and crushing. The fine-grained rock ramifies so irregularly through the porphyritic greenstone that the two are quarried together, though the later rock is the more splintery and tougher. The ploughed fields seem to show that further north, towards Trewalla, there is a separate area of this fine-grained greenstone; but over most of the area scattered fragments of both types can be picked up. None of the other quarries around Tubbs Mill exhibit good sections and they call for no remark. One small exposure of a rock of quite different type will be referred to later on, though we have been unable on the map to distinguish it from the greenstone with which it is associated.

The petrological character of the greenstones have still to be described; but it will be noticed that the field evidence, the appearance to the eye, and the microscopic indications combined still leave some doubt whether any of the rocks in this group are true lavas and tuffs, or whether rocks that appear like ashes are anything but much sheared and brecciated sills. The following petrological notes are by Dr. Teall:—

“The rocks of this group are of pre-Devonian age, with the exception of the mass of Black Head which falls mainly in Sheet 347 and will be described in the memoir on that sheet. They include porphyritic and non-porphyritic basalts of the Mullion Island type, subophitic and ophitic dolerites and epidiorites.

¹ The name ‘Tubbs Mill’ is not on the one-inch map, but all the sign-posts in the neighbourhood point to it. It is the ‘Mill’ half a mile east of Trevennen.

Fragmental rocks of basic composition also occur, but these are undoubtedly in some cases of the nature of fault-breccias, and it is uncertain whether any true tuffs or agglomerates occur in the district.

"The altered basalts of Nare Head (Veryan), Tubbs Mill and Great Perhaver Beach have been described by Mr. Prior¹ who has called attention to their close resemblance to the rocks associated with the radiolarian chert of Mullion Island. A study of numerous specimens of the least altered rocks shows that, apart from the phenocrysts of basic plagioclase which may or may not be present, the original rocks of this type consisted of long, slender, interlacing laths of plagioclase, a small quantity of granular or interstitial augite and a little iron oxide; but it is rare to find a specimen in which all the original minerals are preserved. The secondary constituents include carbonates, chlorite, epidote and less frequently hornblende. In close association with rocks of the above type we find also ophitic and subophitic dolerites.

"The general description given above will suffice for the massive rocks of Great Perhaver Beach and Nare Head; but the rocks of the two quarries at Tubbs Mill deserve a more detailed description. In the upper quarry, as pointed out by Mr. Prior, two varieties occur; a coarsely porphyritic rock composed of numerous white feldspars, often measuring more than a quarter of an inch across, embedded in a compact greenish-grey matrix; and a non-porphyrific rock precisely similar to the matrix of the porphyritic variety. The latter was intruded into the former and passed, at the junction, into a minutely vesicular glass which is now represented by palagonite. The intrusion appears to have been accompanied by the refusion of the ground mass of the porphyritic rock and the isolation of some of the smaller phenocrysts in the palagonite.

"The lower quarry near Tubbs Mill has also yielded two specimens of considerable interest; a fragmental rock containing vesicular lapilli of palagonite which must be either a true tuff or a vesicular glassy rock broken up during or subsequent to consolidation; and a rock illustrating the passage of the compact andesitic basalt into a variolite.

"Fragmental rocks resembling agglomerates are associated with the basalt of Nare Head; but the fragments when examined under the microscope are seen to have been greatly altered and more or less sheared. They consist of epidote, chlorite and a microcrystalline feldspathic aggregate. The original igneous structures have disappeared. Another type of brecciated rock is well exposed in Sunny Corner quarry, near Portloe. The fragments are more or less foliated rocks composed of hornblende, epidote, microcrystalline feldspathic aggregates and iron-ores (scarce). The same minerals occur in the matrix which often shows a well-marked fluxion round the fragments. This rock may be

¹ 'Note on a Pillow-lava apparently forming a continuous horizon from Mullion Island to Gorran Haven in Cornwall.' *Geol. Mag.*, 1904, p. 447.

succinctly described as a brecciated epidiorite. A massive epidiorite with traces of the original igneous structure forms a sill or lava just below the conglomerate at Porthluney.

"In view of the evidence in the Lizard district and elsewhere of the passage of dolerite into epidiorite and hornblende-schists the occurrence of these hornblende rocks in association with basalt of the Mullion Island type is interesting; but it must be clearly understood that no hornblende schists of the prevailing Lizard type have been found in the Gorran and Veryan district."

FELSITIC ROCKS.

Certain bands of pale-coloured igneous rock interbedded in the Ordovician slates, in close proximity to the masses of quartzite, tend to project and form conspicuous points, such as those of Little Perhaver and Greeb. These rocks are confined to a very limited area between Perhaver Beach and Porthluney, though they reappear at the north end of the Lizard peninsula. They are thin sheets of no great thickness, and it is a question whether all the exposures may not belong to folded and sheared repetitions of a single sheet. The rocks are peculiar, and their distribution and behaviour so much suggests beds of volcanic ash that a good deal of time was taken in attempting to obtain good specimens for microscopic examination, unfortunately without any very satisfactory result. The rocks are badly sheared throughout, and they are also much altered, in fact, the alteration has gone so far that the Little Perhaver mass has been recorded by old writers as a 'limestone,' for it is highly calcareous. A glance at the map will show their distribution; but it is practically impossible to follow their weathered outcrops inland. Dr. Teall gives below the result of his petrological examination.

One other rock in the area must be described in this group, though to the eye it is very unlike the pale-coloured doubtful ashes. There is a small, much overgrown quarry on the north side of the high road a quarter of a mile due west of Trevennen, not many yards south-east of the private drive to that house. It is impossible on the map to separate it from the surrounding basalt; but the rock in this quarry is a keratophyre, or soda-felsite.

Felsitic Ash (?).

"The rocks of this somewhat puzzling group are light grey in the interior, but frequently weather buff or brown in consequence of the presence of ferriferous carbonates. Fragmental structures may often be seen on the weathered surfaces, but as the specimens that have been microscopically examined do not show the structure of pyroclastic rocks, it is not improbable that the fragmental character may be the result of the earth movements to which the district has been subjected. In some cases the rocks

have been intensely sheared, and when this is the case a micaceous lustre is seen on the planes of schistosity.

"Specimens from Little Perhaver Point, Greeb Point and Porthluney Cove agree in essential characters. Apart from the carbonates, the secondary mica and the results of dynamic action, the rocks have the composition and structure of soda-felsites or keratophyres. They are essentially composed of phenocrysts of alkali-felspar and more rarely quartz embedded in microcrystalline or microlitic aggregate in which alkali-felspar is also abundant. Tested in the flame of a Bunsen burner by Szabo's method they all show a very strong reaction for sodium. The potassium reaction is always very feeble and often unrecognisable. By this test the rocks of this group can be readily distinguished from the ordinary Cornish elvans which yield a strong potassium and a feeble sodium reaction.

"Carbonates are present in almost all cases, but in variable quantity, and their origin is doubtful. Minute flakes of secondary mica are common, especially in the sheared rocks.

"In this connection attention may be directed to a massive soda-felsite or keratophyre, occurring in the immediate neighbourhood of Trevennen. It is developed on too small a scale to be represented on the one-inch map and, although allied in composition to the rocks above described, is totally different in appearance. It is dark brown, sometimes almost black in colour and porphyritic in texture. The phenocrysts consist of alkali-felspar. The groundmass is composed of microlitic felspars, with which some quartz is probably associated, minute scales of both brown or green and white mica, the latter probably of secondary origin, and a few small specks of iron ore. Long slender prisms of apatite also occur. Some of these rocks are closely allied to the soda-felsite or keratophyre of Bala age occurring at Hamilton Hill in Peeblesshire¹; others differ in containing a considerable amount of biotite in minute overlapping scales."

Dr. W. Pollard has analysed a specimen from a quarry west of Trevennen with the following result :—

SiO ₂	66·05
TiO ₂	·49
Al ₂ O ₃	13·29
Fe ₂ O ₃	3·22
FeO	5·07
MnO	trace.
CaO	·50
MgO	1·36
K ₂ O	·87
Na ₂ O	6·67
H ₂ O 105° C.	·96
H ₂ O above 105° C.	1·88
P ₂ O ₅	·09
Total	100·45

¹ 'The Silurian Rocks of Scotland,' *Mem. Geol. Survey*, 1899, p. 88

QUARTZ-PORPHYRY.

The only representative of this group, so common elsewhere in Cornwall, is a single dyke of 'elvan' running north-west and south-east through the Devonian slates north of Pentewan Harbour. This dyke, however, yields the 'Pentuan stone,' once of great repute for building, though the quarries are now nearly worked out and abandoned. According to De la Beche, it is remarkable for containing fragments of the slate-rocks which it traverses, and occasionally, though very rarely, portions of quartz, which also seem to have been broken off and imprisoned in the matter of the elvan. The fragments, however, actually found in the main body of this elvan are rare compared with those which are detected in a branch it sends off from the cliff where it comes upon the sea, and which runs along the shore towards Black Head. The fragments of the adjoining rocks contained in this branch are extremely numerous, decreasing in abundance from the sides of the dyke towards the central part, where we rarely detect any.

Petrologically this rock is described by Dr. Teall as 'a light grey or cream-coloured quartz-porphyry composed of phenocrysts of quartz and more or less altered orthoclase in a micro-crystalline felsitic matrix. A few scattered plates of muscovite occur also as phenocrysts, and minute flakes of the same mineral form a not inconsiderable portion of the ground mass.'

CHAPTER VI.

DRIFT.

From the Devonian Period onward the geological history of this district is almost unknown, for neither Secondary nor Tertiary deposits are preserved. The flat-topped plateau which forms the uplands probably dates back to Older Pliocene times; but the evidence for this was obtained in other parts of Cornwall, and to the memoirs relating to them the reader is referred, especially to the Memoir on the Land's End.

The Drift deposits represented in this area belong to three stages: 1st, the Raised Beach, formed when the sea-level stood about fifteen feet higher than now; 2nd, the 'Head,' a mass of angular rubble shattered by frost, swept down the slopes, and deposited on the lowlands when arctic conditions prevailed in Cornwall; 3rd, the Alluvium, or muddy and gravelly deposits which fill the larger valleys to a depth near the sea of sixty feet or so. This last was laid down layer by layer in a subsiding area in which the valleys had become sea-lochs or fjords; it alternates with buried land-surfaces or 'submerged forests' which mark the intermittent character of the subsidence.

The continuity of this succession, however, is broken; for we do not understand the abrupt transition from No. 1 to 2, or from No. 2 to 3; but No. 3 itself merges into the recent history of Cornwall, carrying us from Neolithic times to the present day.

RAISED BEACH AND HEAD.

The higher raised beaches of Cornwall do not seem to be represented in this district; but we find here and there ledges or shelves cut into the lower part of the cliff at heights varying from the present level of high water to some 15 or 20 feet higher. Usually the raised beach itself has disappeared and we find only the rocky platform on which it once rested.

Around Pentewan and Mevagissey both beach and shelf have entirely disappeared. Chapel Point shows a wide rocky platform rising to 15 feet above high-water. On this rest small patches of shingle beach, mainly of well-rounded quartz pebbles, hidden under a thick mass of head. In the Raised Beach was found a boulder of gabbro one foot across, but the rest of the material seems to be of local origin. The low cliff of Turbot Point exhibits a clear section of—

Angular loamy head -	-	-	ft.
Thin seam of quartz and slate pebbles, with some quartzite and rare chalk flints	-	-	20
Wide rocky platform about 15 ft. above high-water -	-	-	

At Chapel Point two isolated hillocks of slate surrounded by head seem once to have been outlying stacks in the raised-beach sea.

In Great Perhaver Beach small and narrow relics of the rocky platform enable us to round the points even at high-tide; but no trace of beach is preserved, and even the platform cannot last much longer. Small relics of it also occur between Gorran Haven and Pen-a-maen.

The north end of Vault Beach and Cadythew Rock show the platform excellently; much of it, though swept bare, is so seldom reached by the sea that it is overgrown with lichens and thrift. Small patches of shingle will be found here and there beneath the head, generally preserved in cracks and hollows of the rocks. The old beach deposits have been almost entirely swept out of this bay; but the present cliff-line nearly coincides with the old buried cliff, for here and there the actual wave-worn cliff-face can be seen, well above the reach of the present sea. In this bay a boulder of serpentine was noticed in a crevice in the rocky shore; but it was not quite certain that it belonged to the raised beach. Chalk-flints washed out of this beach are still to be found on the shore.

The old shelf has now entirely disappeared from the foot of the Dodman; though perhaps less than a thousand, and certainly within two thousand years, this narrow ledge must have fringed almost the whole of the coast, giving a practicable and easy communication from bay to bay and rendering the whole coast more accessible than now.

Between Hemmick Beach and Porthluney we here and there find outlying rocks and ledges which seem to be last relics of the platform; but as that platform was originally quite as irregular as the present foreshore, it is not always easy to recognise it. The modern beach in Catasuent and Porthluney Coves contains an exceptional number of Chalk-flints, which probably came from the raised beach.

Just before we reach East Portholland the shelf is again found, and it again appears in the bay north of May's Rock and in Kiberick Cove, though the beach itself has been washed away.

Close to Gidleywell, at the western border of our area, commences the continuous section of Gerrans Bay, which shows for a long distance a low cliff of slate, on which rests a cemented shingle-beach underlying a thick mass of head. The head however is banked against a rocky cliff only a few yards behind the present one, for here and there the deposits have fallen away, laying bare the old wave-worn face. A section within a few yards of Gidleywell showed no less than 40 feet of head, on a thin band of shingle, which again rested on a rocky platform only rising 4 or 5 feet above high-water level.

Unfortunately throughout this area the raised beach is unfossiliferous, so that we can say nothing as to the climatic conditions; the boulder of gabbro occurred at the base of the deposit, and may belong to an older period. Here we have no clear evidence of ice-carried erratics and no evidence of a

submergence greater than 20 feet, though elsewhere in Cornwall both are found.

The head also has here proved to be entirely unfossiliferous ; nor has it yet yielded Palæolithic implements, though the thick masses of Chapel Point and Gerrans Bay are well worth closer search. There is not much head inland, and it there occurs in small patches impossible to map. Where it lies in the valleys it cannot be separated from the next division.

ALLUVIUM AND STREAM-TIN.

Though the whole district is outside the region in which tin-lodes occur, yet three of the streams drain such an area ; consequently the alluvial deposits of each of these rivers has been 'streamed' for the detrital tin-ore which occurs at their base. The excavations made for this purpose have thrown a great deal of light on the later stages of the geology of the district.

As regards the valley of the Fal, though we know that the stream-tin has been removed, there do not seem to be any records as to the nature of the deposits penetrated in the part of the valley that crosses our area. From Borlase we know however that with the tin was found here an exceptional amount of gold, one nugget discovered in 1756 in the parish of Creed weighing 15 dwts. 3 grs.¹

The Porthluney valley has also been streamed for tin, and in it near St. Ewe gold was also found. The valleys that yield gold in unusual quantities all lead up to the granite and metamorphic rocks of St. Stephens.

No details are obtainable as to the alluvial deposits of the Porthluney valley ; but a find of Roman coins a mile from the sea at the edge of the present alluvium, suggests that the valley may then (somewhere between A.D. 253 and A.D. 282) have been a navigable tidal creek up to that spot. Possibly this hoard of about 2,500 brass coins, found in a tin jug, was connected with the stream-tin works of that date, for, as Dr. Haverfield has already pointed out, the stream-works, neglected since the days of Julius Cæsar, were apparently re-opened between 250-400, all the Romano-British vessels or objects of tin or pewter being connected with that period.²

The site of this find was re-examined during the survey ; but it is so overgrown that little can be added, except that near the spot the valley contracts somewhat, as though the estuary were passing into the river. Later working of the alluvial deposits higher up the valley has brought down so much mud that any mounds and trenches left by the Roman workings have been entirely obliterated. This pot of coins, buried just above the level of the highest tides, and, according to Prof. Haverfield, in a small triangular space enclosed by three stones, and resting on

¹ 'Natural History of Cornwall,' p. 214.

² Haverfield, 'On a Hoard of Roman Coins found at Carhayes, Cornwall,' *Numismatic Chronicle*, 3rd ser. vol. XX., 1900, pp. 209-217.

sea-sand, is the only evidence of Roman occupation. But it seems to give us incidentally two important pieces of information; it agrees with other finds in showing that the tin-industry was revived in the third century, and it shows that in Roman times the sea-level was almost the same as now.

The Pentuan Stream-works were some of the most famous in Cornwall, for they were sunk well below the sea-level and exposed excellent sections of the strata traversed, as well as yielding a large amount of tin. The records preserved are most valuable, and make us wish that the works were now open; a number of curious facts were observed, but insufficiently noted in the days when these comparatively modern deposits were little studied, or referred to the action of the deluge.

It is not clear when the earliest stream-works were in operation in Pentewan, but the workings below the sea-level date from 1780, and in time the whole of the alluvium was mined as far as the present coast. Various descriptions have been published, but the best is the excellent one given in 1829 by John W. Colenso.¹ Happy-Union Stream-works lay in the valley near the harbour of Pentuan, and this valley received much of the detrital tin washed down from St. Austell Moor. The fall of its rocky floor from St. Austell to Pentuan is about 45 feet to a mile, the deposit over this floor gradually increasing seaward, till at Happy Union it attained the depth of 60 feet. Colenso's account is so good, and brings out so many points the importance of which has not been noticed by later writers that the following description is merely somewhat condensed from what he wrote.

The rocky floor is composed of blue killas; in particular places the surface appears to be worn by friction. The deposits on it will be taken in order, beginning with the lowest.

The *tin ground* (*a*) is the stratum in which the whole of the stream tin is found. It lies on the solid rock, and is generally from three to six feet and sometimes even ten feet in thickness. It extends across the valley, except where turned by a projecting hill or rock, when it is found to take the supposed ancient course of the river, which is generally under the steepest land. The tin-ground is mainly composed of stones from the St. Austell Moors, all considerably rounded, mixed with angular fragments of the local killas and greenstone. Most of the tin lies at the bottom of the stratum; but sometimes it is found in the higher parts, where for two or three inches in thickness the ground is quite blackened with tin, although perhaps for two or three feet below it does not repay the expense of washing. Generally the smaller the mass of the tin ground the greater the quantity of tin contained in it.

The tin-stone ranges from the finest sand to pebbles of ten pounds weight; and rocks richly impregnated with tin weighing two hundred pounds and upward have occasionally been found. The small tin, which is known as grain tin, is of the best quality; the larger stones contain more waste, and sometimes

¹ 'A Description of Happy-Union Tin Stream-works at Pentuan.' *Trans. R. Geol. Soc. Cornwall*, vol. IV., 1838, pp. 29-39.

also copper and mundic. A few grains and small pieces of gold were found; but they are very scarce, and rarely so large as a pea.

In this stratum Colenso never met with any animal remains; but roots of trees were seen and lately has been opened what was once an oyster bed, on the top of the tin ground, where the shells still remain fastened to some of the large stones, and the stumps of trees. The oak timber was so sound that he was able to use one of the trees to make the axle of a water wheel.

Next follows a stratum of *dark silt* (*b*), about twelve inches thick, apparently mixed with decomposed vegetable matter, and on the top of this is a layer of leaves, hazel nuts, sticks, and moss, from six to twelve inches more. This layer of vegetable matter is about thirty feet below the level of the sea at low water, and about forty-eight feet at spring tides.

The *silt* (*c*) is ten feet in thickness, with shells, wood, hazel-nuts and sometimes bones and horns of deer, oxen, etc. Colenso does not state whether the shells were marine or freshwater, but his fuller account suggests that they belonged to the estuarine *Scrobicularia*. In this silt, about two feet from the top, was found a piece of oak brought into form by the hand of man. It appeared to have floated in the sea, as attached to one end was a small barnacle.

Then follows a stratum of *sea-sand* (*d*), about four inches in thickness. This is easily distinguished from the river-sand, being much finer, and having always shells mixed with it.

Above the sea-sand is found two feet more of *silt* (*e*). About the middle of this stratum is a layer of stones of various sizes and forms, apparently concretions of sand and silt.

More *sea-sand* (*f*), twenty feet in thickness, rests on the silt. In all parts of this sand are timber trees, chiefly oaks, lying in all directions; and also remains of red deer, heads of oxen of a different description from any now known in Britain, the horns of which all turn downwards. Human skulls were also found in this sand, and also nearer the harbour the bones of a large whale.

Bed (*g*) is *rough river-sand and gravel*, here and there mixed with sea-sand and silt. This bed also is about twenty feet in depth, and brings us up to the surface. In this sand near the mouth of the harbour there were found the remains of a row of wooden piles, sharpened for the purpose of driving, which appear to have been used for forming a wooden bridge for foot passengers. The piles crossed the valley, and were about six feet long, their tops being about twenty-four feet from the present surface, just on a level with the present low water at spring tides.

The deposits met with in the Happy Union Stream-works fall into two sharply defined groups. First there is the tin-ground, a coarse gravelly deposit such as could not be transported by the present stream, even with a much greater fall than 45 feet to the mile. It evidently belongs to a time when the land stood fully 50 feet higher than now; when the climate was arctic; and

when sudden rushes of water from the melting snow sufficed to transport coarse material for long distances, especially when buoyed up by ice. The occurrence of iron pyrites and of soluble ores of copper in the larger masses of tin-stone points to rapid tearing up and transportation, not to slow weathering out and transportation by slow stages.

The tin ground is the equivalent of the head, and throws further light on the physical conditions of that period. It proves that after the formation of the raised beach the sea-level must have sunk about 70 feet, allowing the valleys to be deepened and causing the older deposits to be cleared out of all but the widest of them. This seems to be the reason why we so seldom find any trace of the raised beach or of its shelf in Cornish valleys.

After the formation of the tin-ground a series of rapid changes seems to have occurred, and Colenso's evidence, as well as that obtained in other districts, points to a quick but intermittent rise of the sea. Unfortunately the earliest stages are still somewhat obscure; but the growth of oak trees directly on the tin-ground suggests a complete change of conditions, the arctic climate disappearing and the transportation of the flood-material ceasing, though the land still stood at the same high level. We cannot say whether this transition was sudden or gradual; there may here be a gap in the sequence.

The next change must have been rapid, for Colenso's account leaves no doubt that the oak trees while still sound and undecayed were submerged beneath the sea to such a depth that oysters could grow on them, and the oyster under natural conditions is only found well below low-water level. This seems to indicate a subsidence of fully 20 feet within a few years, before the oaks had time to decay, for they would not last if long exposed to the air between tide-marks. The succeeding strata indicate a continuance of this subsidence, with the transformation of the Pentewan Valley into a sea-loch, and then its gradual silting-up.

Unfortunately among the remains of man and the antiquities no tools of metal or stone were found to fix the exact periods represented. We have probably at Pentewan a continuous sequence of deposits belonging to the Neolithic, Bronze, and Iron ages, for elsewhere the submerged forests yield polished-stone tools.

CHAPTER VII.

ECONOMICS.

At present little quarrying and no mining is carried on in the district, and the quarrying is only for local use. Formerly however, much stream-tin was obtained; but this has now been completely removed. Ochre was also mined for a short time; but did not pay. The other shafts and levels only represent unsuccessful trials. The Pentewan-stone quarries once had a considerable reputation, as yielding almost the only fine-grained freestone in this part of Cornwall: they are no longer worked.

STREAM-TIN.

As was shown in the last chapter, alluvial tin has been obtained in the valley of the Fal near Creed, in the Porthluney valley, and in the St. Austell valley below the sea-level near Pentewan. There does not appear to be any existing record showing separately the amount obtained from the different valleys; but as regards Pentewan, Colenso's paper, already cited, gives in a footnote (p. 32) certain particulars which enable us to make a rough calculation.

The tin-oxide or cassiterite is very heavy, in fact more than twice the weight of the accompanying stones, and is almost entirely confined to a thin layer of gravel, known as the 'tin-ground,' at the bottom of the alluvial deposits and resting on a floor of solid rock. Here and there, however, a little tin has been found on higher levels. At some of the Pentewan works the great thickness of the alluvium, and the position of the tin-ground far below the sea-level, necessitated actual mining; though in shallower alluvium the whole mass is turned over till the tin-ground is reached. In this case pits were sunk through the alluvium and the gravel was mined beneath, as far as it could conveniently be reached from that pit, which was then abandoned and another sunk.

As regards the amount obtained within our area, Mr. Colenso's statement is that 'the quantity of tin ground opened at Pentewan has been seven hundred fathoms in length, averaging about twenty-six fathoms in breadth, making a total of eighteen thousand and two hundred square fathoms. The average quantity of black tin gotten per square fathom has been one hundred and eighty pounds: the quantity of overburthen removed has been upwards of two hundred thousand tons.' That is to say each mile in length of the lower part of the St. Austell valley yielded something like 2,190 tons of black tin, which would give about 1,500 tons of 'grain tin' (which yields the best quality of metallic tin), of a value of about £120,000.

No other metallic minerals appear to have been mined in this area, though one occasionally finds traces of copper, and as already mentioned, gold occurs with the stream-tin. It was thought that the Devonian conglomerate might possibly yield alluvial gold or platinum, derived from the Lower Palæozoic rocks or Serpentine. An assay was therefore made of the rock from Porthluney; but Mr. MacAlister was unable to find either metal.

OCHRE.

A certain amount of ochre was dug at Great Perhaver, the iron stage on the foreshore being connected with this mine. The ochre was obtained from the decayed surface part of the pillow-lava in the fields above. It did not pay.

There are also one or two trial-levels in the cliffs near red springs. These seem to have been made also in search of ochre or iron-ore; but none was worked. One of these trials will be seen near Black Rock.

BUILDING STONE.

None of the building stones, with the exception of the Pentewan elvan, are of sufficient value to be carried more than two or three miles. It is possible nearly everywhere to obtain rough stone suitable for cottages and field-walls, but the 'Pentuan-stone' is the only freestone, and its quarries are now practically worked out. The quarries are in an elvan dyke and were worked at the edge of the cliff; the stone was formerly used in church-building over a considerable area. It is also interesting to notice that the Roman inscribed stone built into the wall of Tregoney church is also a rough block of this material; the inscription being cut through a thin film of-quartz on a flat natural joint-face.

Though the killas is occasionally dressed with an axe, more commonly the blocks are used as they come out of the quarry joint-faces being selected for the outside, as being both neater and more impervious. Masses of quartzite and of Devonian grit are also built in, but these are so hard and of such unmanageable shapes that they are generally only used for facing banks, if the flatter-bedded slate is to be had.

Roofing slates and flags were once worked near Tregian, in St. Ewe parish; but the quality is very poor and they cannot compete with Delabole. For mortar beach-sand is commonly used; lime has to be imported.

AGRICULTURE.

The land is usually a loam of fair quality, especially where there is a mixture of decayed igneous rock or dunstone. The general southward slope tends to give it a good aspect and shelter from the north.

Though the land is good, there is a considerable proportion of uneven swampy ground in the valley-bottoms, and sometimes on the gentler slopes. This is difficult to use in any way except as rough pasture or ozier-ground. The wet land often extends a good way beyond the limit of the alluvium, and its swampy nature is generally due to the oozing out of water for some height above the valley-bottom. Many of the valleys have been cut well below the level of the present plane of saturation, so that they now tend to fill up rather than to become deeper.

The accumulation of washed material in the valleys tends greatly to increase the depth of the soil in their bottoms, so that the streams seldom flow over a bed of live rock. In this respect Cornwall is in striking contrast with the north country. Over the flat-topped tableland there is also a tendency for weathered material to accumulate; but in this case it is an accumulation of vein-quartz, left behind as the fine material of the weathered killas is washed into the valley. Some of the flatter uplands are excessively stony, and yet there is no very large amount of vein-quartz in the slate a few inches below. On the slopes the soil is so thin that slate is constantly ploughed up.

WATER SUPPLY.

Though the rainfall is copious and there are plenty of small springs, the water supply is scarcely satisfactory. Nearly everywhere a well will yield enough water for a house or farm; but it is not easy to find uncontaminated springs large enough to supply a village. The water is also a good deal harder than would be expected, that coming from the igneous rocks having such an excess of lime that it commonly deposits tufa.

APPENDIX.

LIST OF PRINCIPAL WORKS ON THE GEOLOGY OF THE DISTRICT.

1602. CAREW, R. C. Survey of Cornwall, 4to.
1758. BORLASE, Rev. W. The Natural History of Cornwall, fol., Oxon.
1817. SMITH, E. On the Stream-works at Pentowan, *Geol. Trans.* vol. iv., p. 404.
1818. ROGERS, Rev. J. Observations on the Limestone of Veryan and the neighbouring parishes. *Trans. R. Geol. Soc. Cornwall* vol. i., p. 114.
- TRIST, S. J. Notes on the Limestone Rocks in the Parish of Veryan. *Ibid.*, p. 107.
1832. BOASE, Dr. H. S. Contributions towards a knowledge of the Geology of Cornwall. *Ibid.*, vol. iv., pp. 166-474.
1839. DE LA BECHE, Sir H. T. Report on the Geology of Cornwall, Devon, and West Somerset. *Geological Survey*, 8vo., London.
1841. PEACH, C. W. An account of the Fossil Organic Remains found on the South-east coast of Cornwall, and in other parts of that county. *Trans. R. Geol. Soc. Cornwall*, vol. vi., p. 12.
- On the Geology of part of the Parish of Gorran, in Cornwall. *Ibid.*, p. 51.
1842. — On the Fossil Geology of Cornwall. *Ibid.*, p. 181.
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PLATE I.

‘PILLOW-LAVA’ OF GREAT PERHAVER.

(Photographed by T. C. Hall.)

North face of Great Perhaver Point, as seen from the iron shipping-stage of the ochre-mine. The cliff is about 120 feet high, the scale being shown by the man pointing to a pillow just above high-water level in the middle of the photograph.

The photograph shows a joint face which cuts across the lenticles nearly at right-angles. The rock is basalt, resting on the right (outside the photograph) on black slate with thin radiolarian chert; but the succession is probably inverted. The notch at the top of the cliff shows the position of the ochre mine, formerly worked in the highly ferruginous decayed basalt (see also pp. 12, 13, 51–54, 65).

This photograph is No. 128 in the Geological Survey Collection of British Photographs.



PLATE 2.

CURVED SLICKENSIDES IN QUARTZITE.

(Photographed by T. C. Hall.)

A large fallen block near the path to the shore at Great Perhaver Beach. Its size is shown by the hammer. It is lenticular in shape and exhibits curved slickensides. These were at one time interpreted as glacial striæ; but it will be seen that one curved striated surface passes through and behind another (see also p. 14).

This photograph is No. 130 in the Geological Survey Collection of British Photographs. No. 129 (not reproduced) illustrates the enormous amount of shattering and quartz-veining seen in an adjoining block. No. 131 (not reproduced) shows the mode of occurrence of these lenticles amid the slates.



PLATE 3.

HONEYCOMB WEATHERING IN DODMAN SLATES.

(Photographed by T. C. Hall.)

Between tide-marks west of Hemmick Cove. This type of weathering is very common in Cornwall, and occurs in rocks of various compositions. It corresponds with no internal structure in the rock and is probably of organic origin (see also p. 17).

This photograph is No. 140 in the Geological Survey Collection of British Photographs.



PLATE 4.

ARCHED CLEAVAGE SHEARED VERTICALLY.

(Photographed by T. C. Hall.)

Cliff on the west side of Hemmick Cove (scale indicated by hammer). Arched striped and cleaved Dodman phyllite, cut by strong vertical strain-slip cleavage. Owing to the difficulty of lighting the curved face, oblique illumination could not be used and the vertical cleavage is less conspicuous than it should be. It shows best just below the hammer (compare with Plate 5, and see also p. 17).

This photograph is No. 135 in the Geological Survey Collection of British Photographs.

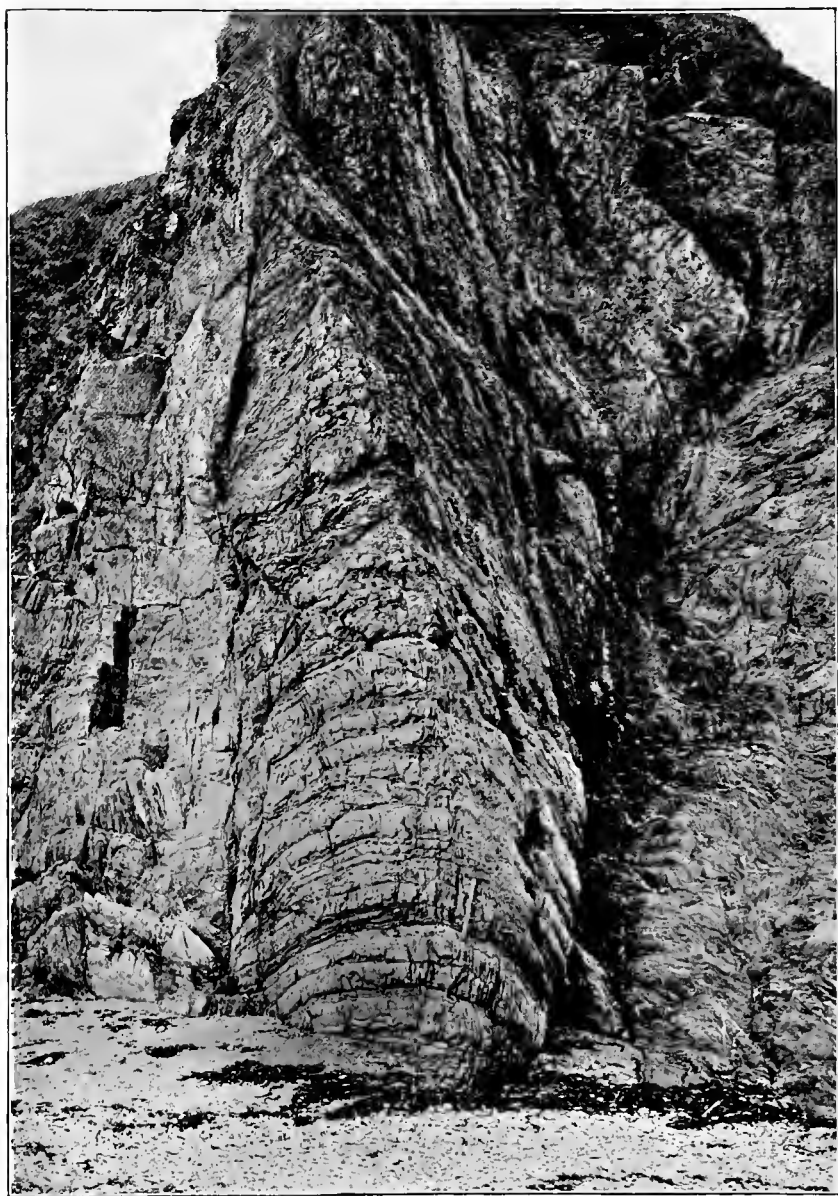


PLATE 5.

BANDED ROCK SHEARED VERTICALLY.

(Photographed by T. C. Hall.)

Wave-worn face of banded slate, on a half-tide rock on the west side of Hemmick Cove. Contorted banded Dodman phyllite is sheared vertically across the contortions (compare with Plate 4, and see also p. 18).

This photograph is No. 136 in the Geological Survey Collection of British Photographs. A photograph of another surface (No. 137, not reproduced) shows only a faint trace of the vertical shearing.



PLATE 6.

OVERTHRUST FAULT NEAR CADYTHEW ROCK.

(Photographed by T. C. Hall.)

Cliff about 80 feet high, west of Hemmick Beach, seen from the south-west. The photograph illustrates a low-hade overthrust fault, sloping upwards from the cave. The strata below the fault consists mainly of grey slate, with a large lenticle of felspathic ash, forming the detached rocks in the foreground. This lenticle narrows rapidly, so that at the foot of the cliff, on the left of the cave, it is only two or three feet thick. Above the fault is sheared slate full of lenticles of quartzite, some of which form the conspicuous white masses just above the beach on the right of the cave. At the upper right hand corner is felspathic ash, like that below the fault (see also p. 18).

This photograph is No. 138 in the Geological Survey Collection of British Photographs. No. 139 in the Survey Collection, not reproduced, shows a near view of part of this overthrust.



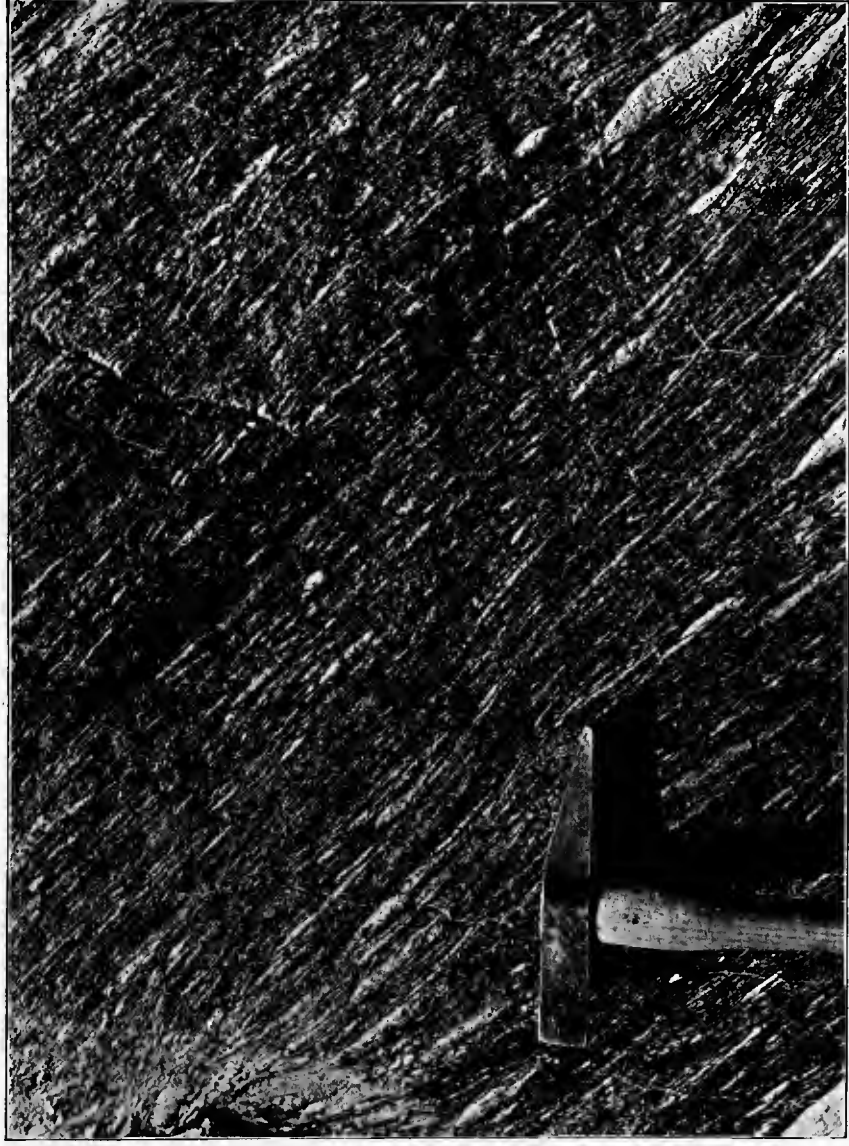
PLATE 7.

CRUSH-BRECCIA, PORTHLUNEY.

(Photographed by T. C. Hall.)

Crush-breccia of slates of different colour, with small lenticles of igneous rock, seen in the lower right-hand corner. This photograph shows the general structure of the area, which is similar under the microscope, or on a large scale, with lenticles a hundred yards long. The quartzite lenticles are short and thick, and cause more irregularity; one small one is seen in this photograph, just above the centre (see also p. 22).

This photograph is No. 134 in the Geological Survey Collection of British Photographs.



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